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REVIEW OF THE RELATION OF DENSITY AND REFRACTIVE INDEX TO THE COMPOSITION OF GLASS: I*

By Kuan-Han Sun, Hurd W. Safford, and Alexander Silverman

Abstract

The density, refractive index, and specific refractivity and their relationship to the composition of glass are discussed. The subject is treated from the standpoint of additive properties based on composition both as to linear and collective or complex functions. Not only are these applied in the rapid checking of constancy of composition in practice but also from the standpoint of possible changes in properties through partial changes of individual components. There is the further possibility of tying up constitution with composition so that a structural analysis may result. The article serves as a review of existing literature and elaborates the possibility of expansion of published data.

NOTATIONS

Various authors have adopted different symbols for the same expression. For simplification, the following unified notations will be used:

p_X	= weight percentage of X.†
P_X	= mole percentage of X.
q_X	= volume percentage of X.
w_X	= weight units of X.
m_X	= moles of X.
d	= density of glass.
d_X	= density factor for X.
n	= refractive index of glass with respect to sodium D-line.
n_X	= refractive index factor for X with respect to sodium D-line.
(n_C)	= refractive index of glass with respect to hydrogen C-line (similar notations for lines of other wave lengths).
$(n_C)_X$	= refractive index factor for X with respect to hydrogen C-line.
v	= specific volume of glass.
v_X	= specific volume factor for X.
k	= specific refractivity of glass.
k_X	= specific refractivity factor for X.
M	= mean molecular weight of glass.
M_X	= molecular weight of X.
V	= molecular volume of glass.
V_X	= molecular volume factor for X.
K	= molecular refractivity of glass.
K_X	= molecular refractivity factor for X.

I. Introduction

A knowledge of the density of glass is important for several reasons. The pressure exerted by fluid glass on the walls of a containing vessel is proportional to the density; the design of the tank or pot is therefore related thereto. Layers of various densities produce waves, cords, and striae. As will be shown later, specific refractivity is linearly additive for most glasses, and refractive index may be calculated accurately if the density is known. In certain work, a definite volume of glass may be needed, and it is necessary to figure the amount of batch and the density of the product. Density affects the production cost of articles because the weight per piece depends on it. Density measurement affords a quick check on composition in a plant during routine production. This point will be clarified later in a discussion of change of density with change of composition.

Refractive index is important in the field of optical glass, particularly in the design of optical systems. Dispersion, Abbé value or dispersive index, reflectivity (Fresnel relation), and brilliancy are all directly related to index of refraction.

The purposes of the correlation of density and refractive index with composition are (1) calculation of properties of glass from composition without making melts; (2) indication, prediction, and estimation of properties of new glasses; (3) as the reverse of case (1), it will afford an indication of mistakes by checking density or refractive index of glass; (4) the correlation, if expressed in mathematical equations or graphic forms, will serve to present results of research for visual inspection; and (5) some indications as to constitution of glass may be predicted.

A review of existing incomplete data, supplementing these to obtain complete data with generalizations, should help the glass technologist.

II. Relation Between Composition and Density

Density of glass is weight per unit volume; specific volume is volume per unit weight. Specific or molecular volume, rather than density, indicates the validity of linear additive relationships.‡

(A) Additive Calculations

(1) Oxide Factors

Winkelmann and Schott[1] calculated approximate densities from composition by the linearly additive formula, equation (1).

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Contribution No. 398 from the Department of Chemistry, University of Pittsburgh.

Part II of this paper will appear in the December issue of *The Journal*.

† X represents any glass constituent A, B, or C. . . .

‡ Additive relationships are "linear" or "complex."

[1](a) A. Winkelmann and O. Schott, "Über thermische Widerstandscoefficienten verschiedener Gläser in ihrer Abhängigkeit von der chemischen Zusammensetzung," *Ann. Phys. Chem.*, **51**, 730–64 (1894).

(b) H. Hovestadt, Jena Glass and Its Scientific and Industrial Applications (translated by J. D. Everett and Alice Everett). Macmillan & Co., London, 1902.

$$\frac{100}{d} = \frac{p_A}{d_A} + \frac{p_B}{d_B} + \frac{p_C}{d_C} + \ldots\ldots \quad (1)$$

wherein d = density of glass.
p_A, p_B, etc. = weight percentages of components A, B, etc.
d_A, d_B, etc. = density "factors" for these components.

Their density factors (Table I), derived from ninety-one unanalyzed glasses, were empirically calculated on the supposition that oxides have unvarying densities. Their results do not entirely justify this assumption, as the deviations range from 1½ to 10%. Winkelmann and Schott admit that these relations are applicable only to glasses similar in composition to those from which the density factors were obtained.

English and Turner[2] found that the application of the factors of Winkelmann and Schott to seventeen soda-lime-silica glasses produced marked discrepancies.

Tillotson[3] indicated the inadequacy of the Winkelmann and Schott figures when they were applied to the calcium and magnesium-metasilicate glasses of Larsen, the lithium-calcium-metasilicate glasses of Wallace, and the mixed feldspar glasses of Day and Allen. He claimed greater accuracy from factors based on a constant value for SiO_2 (Table I).

In a test of ninety-one glasses, Baillie[4] found better agreement with experimental values when constants (Table I) were used empirically evaluated from the formula, equation (2).

$$\frac{\Sigma p}{d} = \frac{p_A}{d_A} + \frac{p_B}{d_B} + \frac{p_C}{d_C} + \ldots\ldots \quad (2)$$

wherein Σp = sum of oxide percentages determined by chemical analysis.

If the analytical results be in error by amounts α, β, γ. . . . . ν, he considered the correct density, d', to be expressed by equation (3).

$$d' = d\left(\frac{100 + \Sigma(\alpha)}{100 + d\cdot\Sigma(\alpha/d_X)}\right). \quad (3)$$

The differences between $\Sigma(\alpha)$ and $d\cdot\Sigma(\alpha/d_X)$ in general are slight so that the discrepancies due to allowable analytical variations are small.

English and Turner[5] considered the density of SiO_2 to be unchanged when it is present in a silica glass. Their factors (Table I), calculated from the densities of specially prepared two-component, oxide-silicate glasses, compared favorably with the constants determined by Baillie, and this led them to recommend that the figures of Winkelmann and Schott be discarded.

That their factors for Al_2O_3 and CaO were more suitable to the system soda–alumina–lime–silica than to the system soda–alumina–silica further indicated the limitations of density factors. Caution should be exercised in the use of such constants unless the number of components and the range of composition are limited.

English, Howes, Turner, and Winks[6] prepared ten glasses of the general formula, $6SiO_2\cdot(2-x)Na_2O\cdot xFe_2O_3$. Partial reduction of ferric oxide during melting produced variations of 2 to 22% of ferric oxide and 0.6 to 4% of ferrous oxide. From their previously determined factors for SiO_2 and Na_2O, they additively evaluated the constants for FeO and Fe_2O_3 (Table I).

TABLE I

DENSITY FACTORS

Column (1) Winkelmann and Schott[1]; (2) Tillotson[3]; (3) Baillie[4]; (4) English and Turner[5]; (5) Turner [6,7] and others[8]; (6) Fuwa.[9]

	(1)	(2)	(3)	(4)	(5)	(6)
P_2O_5	2.55					
As_2O_5	4.1					
Sb_2O_4			3.00			
SiO_2	2.3	2.3	2.24	2.20		
B_2O_3	1.9	2.24	2.90			
Al_2O_3	4.1	2.75	2.75	2.75		
Fe_2O_3					4.8	4.8*
As_2O_3			3.33			
MgO	3.8	4.0†	3.25	3.38		
CaO	3.3	4.1	4.30	5.00	5.1	
FeO					3.0	7*
ZnO	5.9		5.94		7.5	
BaO	7.0		7.20			
PbO	9.6		10.30			
Li_2O		3.7			3.2	3.16
Na_2O	2.6	2.8	3.20	3.47‡	3.5	
K_2O	2.8		3.20		3.0	2.88
Rb_2O					4.45	

* For soda- and potash-containing glasses; for lithia-containing glasses, the factors were Fe_2O_3 = 6 and FeO = 8.

† 4.3 in presence of alkali.

‡ 3.38 to 3.4 for soda-silica glasses.

Experimental studies of glasses of the general formula, $6SiO_2\cdot(2-x)Na_2O\cdot xZnO$, enabled English, Turner, and Winks[7] to calculate a new density factor for ZnO (Table I).

Waterton and Turner[8] investigated glasses of the type $75SiO_2\cdot 10CaO\cdot 15(R'_2O + R''_2O)$, where $(R'_2O +$

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[2] S. English and W. E. S. Turner, "Density of Soda-Lime Glasses," *Jour. Soc. Glass Tech.*, **4**, 126–28 (1920).

[3] (*a*) E. W. Tillotson, Jr., "Density of Silicate Mixtures," *Jour. Ind. Eng. Chem.*, **3** [12] 897–900 (1911).

(*b*) E. W. Tillotson, Jr., "Density of Some Borate and Silicate Glasses," *ibid.*, **4** [11] 820–21 (1912).

[4] W. L. Baillie, "Relation Between Density and Composition of Glasses," *Jour. Soc. Chem. Ind.*, **40** [12] 141–48 (1921); *Ceram. Abs.*, **1** [5] 145 (1922).

[5] (*a*) S. English and W. E. S. Turner, "Density of Soda-Magnesia Glasses," *Jour. Soc. Glass Tech.*, **4**, 153–57 (1920).

(*b*) S. English and W. E. S. Turner, "Density of Glasses Containing Aluminum," *ibid.*, **5**, 277–80 (1921); *Ceram. Abs.*, **1** [6] 166 (1922).

(*c*) S. English and W. E. S. Turner, "Density of Soda-Lime-Magnesia Glasses and Calculation of Density," *Jour. Soc. Glass Tech.*, **6**, 228–31 (1922); *Ceram. Abs.*, **2** [10] 219 (1923).

[6] S. English, H. W. Howes, W. E. S. Turner, and F. Winks, "Influence of Iron Oxide on Properties of Glass," *Jour. Soc. Glass Tech.*, **12** [45] 31–52 (1928); *Ceram. Abs.*, **8** [1] 23 (1929).

[7] S. English, W. E. S. Turner, and F. Winks, "Some Properties of Glasses Containing Zinc Oxide," *Jour. Soc. Glass Tech.*, **12** [48] 287–96 (1928); *Ceram. Abs.*, **9** [8] 624 (1930).

[8] S. C. Waterton and W. E. S. Turner, "Properties of Mixed Alkali-Lime-Silica Glasses Containing Lithia, Soda, Potash, and Alumina," *Jour. Soc. Glass Tech.*, **18** [72] 268–85 (1934); p. 283; *Ceram. Abs.*, **14** [8] 186 (1934).

[9] Kitsuzo Fuwa, "Glasses Containing Iron Oxide: XV, Density of Glass," *Jour. Japan. Ceram. Assn.*, **46**, 8–11 (1938); *Jour. Soc. Glass Tech.*, **22** [90] 129A (1938); *Ceram. Abs.*, **19** [5] 110 (1940).

R''_2O) represents (Li_2O + Na_2O), (Li_2O + K_2O), (Na_2O + K_2O), and (K_2O + Rb_2O). New constants for Li_2O, Na_2O, K_2O, and Rb_2O were thus established (Table I).

Fuwa,[9] employing equation (1) and the factors of Turner and others, obtained different values for Li_2O, K_2O, FeO, and Fe_2O_3 (Table I). Reasonable agreement with experimental densities was claimed.

Peddle[10] applied the Winkelmann and Schott factors to nine unanalyzed glasses and found discrepancies between calculated and experimental density values. Density-composition curves for many glasses[11] led him to question the validity of linear additive expressions when applied to wide ranges in composition.

English and Turner[12] studied two series of glasses, $20Na_2O\cdot(80-x)SiO_2\cdot xB_2O_3$ and $10Na_2O\cdot(90-x)\,SiO_2\cdot xB_2O_3$, in which x was varied, respectively, from 0 to 43 and 12 to 46 weight per cent. In the first series, the density rose to a maximum on plotting it against percentage of B_2O_3; in the second series, the corresponding curve fell to a minimum. They attributed these maxima and minima to the presence of definite compounds. Cousen and Turner[13] found that for boric oxide-silica glasses density increases continuously with silica content. Their density-percentage B_2O_3 curves are approximately linear and contain neither maxima nor minima. The peculiar behavior of boric oxide is explained by Warren[14] through X-ray investigations of soda-boric oxide and boric oxide-silica glasses.

Finn and Thomson[15] introduced a mathematical derivation of density factors. They assumed change in density to be a function of percentage composition, and they determined partial densities* from equation (4).

$$d'_X = a(p_X + c)^b, \qquad (4)$$

wherein d'_X = partial density factor for any component X.
p_X = percentage of X.
a, b, and c = numerical constants.

The density, d, of the complex glass was derived from the sum of the partial densities in equation (5).

$$d = d'_A + d'_B + d'_C + \ldots\ldots \qquad (5)$$

The constants a, b, and c, evaluated for SiO_2 and Na_2O from the soda-silica glasses of Peddle, were used to obtain constants for CaO, MgO, and Al_2O_3 from the soda-lime-silica, soda-alumina-silica, and soda-magnesia-silica glasses of Peddle, English, and Turner (Table II).

TABLE II

CONSTANTS FOR DENSITY CALCULATION AFTER FINN AND THOMSON[15]

	Percentage range	a	b	c
SiO_2	50–85	0.33250	0.4463	−30.0
Na_2O	15–50	0.01869	1.0810	0
CaO*	3–24	0.03365	0.9887	0
CaO†	3–24	0.02813	1.0350	0.2
MgO	1–10	0.30170	0.9262	0
Al_2O_3	3–13	0.00675	1.3571	3.0

* From soda-lime-silica glasses of Peddle.
† From soda-lime-silica glasses of English and Turner.

The method improved density calculations, but the incorrect assumption that the values of a, b, and c are the same for SiO_2 and Na_2O in all glasses renders the constants for CaO, MgO, and Al_2O_3 "apparent" rather than "partial."

Gehlhoff and Thomas[16] chose a parent glass of the composition SiO_2 82% and Na_2O 18%, replaced the silica by successive additions of CaO, MgO, ZnO, PbO, B_2O_3, Al_2O_3, and Fe_2O_3, and determined densities for the resulting glasses. Following a graphic treatment of the data, constants were calculated for each 5% increment of substituted oxide (Table III). The known density of a parent glass enables that property to be derived for other members of the same or different series.

Densities calculated from these constants for three soda-lime-silica and six soda-lime-magnesia-silica glasses,[17] agreed within 0.2% of experimental values.

Turner[18] and English and Turner,[19] studying the effects of MgO, CaO, ZnO, BaO, Al_2O_3, and ZrO_2, constructed density-percentage RO, R_2O_3, and RO_2 curves for glasses of the general formula $6SiO_2\cdot(2-x)Na_2O\cdot xRO(R_2O_3)(RO_2)$. Although the linear addition rule was upheld, the mode of preparation and heat treatment of the glass was important.

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[10] C. J. Peddle, "Development of Various Types of Glass: I, Interaction of Silica with Oxides of Sodium and Potassium," *Jour. Soc. Glass Tech.*, **4**, 2–20 (1920); p. 8.

[11] C. J. Peddle, *ibid.*, Vol. 4 (1920) and Vol. 5 (1921).

[12] S. English and W. E. S. Turner, "Physical Properties of Boric Oxide-Containing Glasses and Their Bearing on the General Problem of the Constitution of Glass," *ibid.*, **7** [26] 155 (1923); *Ceram. Abs.*, **3** [2] 36 (1924).

[13] Arnold Cousen and W. E. S. Turner, "Study of the Glasses Boric Oxide-Silica," *Jour. Soc. Glass Tech.*, **12**, 169–90 (1928).

[14] (*a*) J. Biscoe and B. E. Warren, "X-Ray Diffraction Study of Soda-Boric Oxide Glass," *Jour. Amer. Ceram. Soc.*, **21** [8] 287–93 (1938).

(*b*) J. Biscoe, C. S. Robinson, Jr., and B. E. Warren, "X-Ray Study of Boric Oxide-Silica Glass," *ibid.*, **22** [6] 180–84 (1939).

[15] A. N. Finn and H. G. Thomson, "Density and Index of Refraction of Glass vs. Its Composition," *ibid.*, **8** [8] 505–13 (1925).

* Partial density is that part of the density of glass attributable to any special oxide.

[16] (*a*) G. Gehlhoff and M. Thomas, "Physical Properties of Glass in Relation to Its Composition: I, Electrical Conductivity of Glasses," *Z. tech. Physik*, **6**, 544–54 (1925); *Ceram. Abs.*, **5** [6] 178 (1926).

(*b*) "II, Mechanical Properties," *Z. tech. Physik*, **7**, 105–26 (1926); *Ceram. Abs.*, **5** [11] 353 (1926).

[17] "Use of Gehlhoff and Thomas Specific Effect Data in Practice," *Glass Ind.*, **18** [7] 227–29 (1937).

[18] W. E. S. Turner, "Physical Properties of Glasses; Relationship to Chemical Composition and Mode of Preparation," *Jour. Chem. Soc.*, **129**, 2091–2116 (1926); *Ceram. Abs.*, **6** [3] 101 (1927).

[19] S. English and W. E. S. Turner, "Properties of the Soda-Baryta-Silica Glasses and a Comparison with Corresponding Soda-Lime and Soda-Lead Oxide-Silica Glasses," *Jour. Soc. Glass Tech.*, **11** [44] 425–32 (1927); *Ceram. Abs.*, **7** [5] 284 (1928).

TABLE III

DENSITY CONSTANTS* (AFTER GEHLHOFF AND THOMAS[16])

Parent glass	Range (%) 0–5	5–10	10–15	15–20	20–25	25–30	30–40	40–50	50–60
Na_2O { $80SiO_2$·-			0.0017	0.010	0.008	0.006			
K_2O { $20PbO$				0.005	0.003				
MgO { $82SiO_2$·-	0.012	0.012	0.006	0					
CaO { $18Na_2O$	0.018	0.016	0.014	0.012	0.009	0.007			
ZnO "	0.021	0.021	0.021	0.021	0.021	0.021			
BaO "	0.024	0.024	0.024	0.024	0.024	0.024	0.024		
PbO "	0.024	0.024	0.026	0.027	0.029	0.032	0.034	0.037	
B_2O_3 "	0.018	0.010	0.003	0	−0.004	−0.005	−0.005	−0.006	−0.006
Al_2O_3 "	0.006	0.006	0.006						
Fe_2O_3 "	0.013	0.013	0.013	0.013	0.013	0.013			

* Values given are for 1% by weight of substituted oxide.

Moriyasu[20] has given equations (6) and (7) for the volume, V', of soda-silica glass composed of 6000 parts of SiO_2 and $62 \cdot y$ parts of Na_2O:

$$\text{For } y < 50,\ V' = 2694 + 0.3084 \cdot y. \tag{6}$$

$$\text{For } y > 70,\ V' = 2464 + 0.3677 \cdot y. \tag{7}$$

Moriyasu, claiming good agreement of these density moduli with those of Baillie and English and Turner when y was smaller than 50 and with those of Winkelmann and Schott when y was greater than 70, represented the volume change at y equals 50 to indicate the presence of $Na_2O \cdot 2SiO_2$. Conclusions favoring compound existence in glass, often based on inaccurate, insufficient data and false correlation of curve slope-shifts with compound compositions, are partially refuted by modern concepts of structure.

For soda-silica glasses containing less than 80% of SiO_2, the Bureau of Standards[21] obtained smooth density-composition curves. Empirical equations (8), (9), and (10), for the range 50 to 80% of silica, follow.

$$d = 0.07977(86.5 - p_A)^{0.42187} + 2.203, \tag{8}$$

$$d = 0.00301 \cdot p_B - \frac{2.988}{(p_B - 1)} + 2.4756, \tag{9}$$

$$d = 0.3293(p_A - 30)^{0.4486} + 0.01873(p_B)^{1.0803}, \tag{10}$$

wherein p_A and p_B = respective weight percentages of SiO_2 and Na_2O (equations (8) and (9) are complementary, and their usefulness is restricted by limited application).

Winks and Turner,[22] plotting specific volume against percentage composition for fifteen soda-silica glasses, found approximate linear relations from 65 to 92% of SiO_2 but greater deviations from 51 to 65%. Equations (1), (9), and (10), tested with the data, gave good results in four, three, and eight cases, respectively.

Glaze, Young, and Finn[23] found that when specific volume-percentage silica curves for soda-silica glasses were segmented into straight lines, they produced intersections corresponding to Na_2O–SiO_2 ratios of 4:6, 3:6, and 2:6. Empirical constants, a and b, evaluated for each segment, enabled densities to be calculated from equation (11).

$$1/d = a \cdot p_A + b \cdot p_B, \tag{11}$$

wherein p_A and p_B = percentages of silica and soda, respectively.

Finn and his associates,[23] employing equation (11) and considering lime plus soda as total soda, calculated $1/d$ values for twenty-two glasses whose compositions ranged from 50.0 to 80.5% of SiO_2, 16.2 to 37.8% of Na_2O, and 3.2 to 12.0% of CaO. Differences between computed and observed specific volumes, plotted as a function of CaO percentage p_C, produced equation (12) for each linear segment of the curve as follows:

$$f(p_C) = c \cdot p_C + c' \cdot p^2_C. \tag{12}$$

Equation (13) results from the addition of equations (11) and (12). Values for constants a, b, c, and c' are given in Table IV.

$$1/d = a \cdot p_A + b \cdot p_B + c \cdot p_C + c' \cdot p^2_C. \tag{13}$$

For any particular series, specific volume varied directly as the silica content. It was suggested that these soda-silica glasses should be regarded as simple compounds or as mixtures of two adjacent compounds.

Gilard and Dubrul introduced a new formula, equation (14).[24]

[20] Shizuta Moriyasu, "Relation Between Composition and Specific Gravity of Glass," *Jour. Japan Ceram. Assn.*, **38** [456] 795–802 (1930); *Ceram. Abs.*, **11** [7] 405 (1932).

[21] (*a*) "Density and Composition of Soda-Silica Glasses," *Jour. Franklin Inst.*, **210**, 251 (1930); *Ceram. Abs.*, **10** [4] 259 (1931).

(*b*) Annual Report of Director of Bureau of Standards, June 30, p. 25 (1930).

(*c*) "Relation Between Chemical Composition, Index of Refraction, Density, and Thermal Expansion of Soda-Lime-Silica Glasses," *Ceram. Age*, **17** [3] 133 (1931).

[22] F. Winks and W. E. S. Turner, "Density of Sodium Metasilicate-Silica Glasses," *Jour. Soc. Glass Tech.*, **15** [58] 185–90 (1931); *Ceram. Abs.*, **10** [9] 630 (1931).

[23] F. W. Glaze, J. C. Young, and A. N. Finn, "Density of Some Soda-Lime-Silica Glasses as a Function of Composition," *Jour. Research Nat. Bur. Stand.*, **9**, 799–805 (1932); R. P. 507.

[24] Pierre Gilard and Léon Dubrul, "Calculation of Physical Properties of Glass: II, Expansion and Density," *Verre & Silicates Ind.*, **9** [3] 25–28; [4] 37–39; [5] 50–52 (1938); *Ceram. Abs.*, **18** [4] 95 (1939).

TABLE IV

DENSITY CONSTANTS AFTER GLAZE, YOUNG, AND FINN[23]

SiO_2 limits (SiO_2 wt. %)	$aX10^1$	$bX10^3$	$cX10^3$	$c'X10^6$
50(?)–p_A	4.252	3.537	2.545	8.0
p_A–p'_A	4.3028	3.4628	2.500	4.0
p'_A–p''_A	4.3922	3.2872	2.285	5.0
p''_A–100	4.5400	2.8460	1.844	14.8

$$p_A = 59.4 - 0.23 \cdot p_C + 0.032 \cdot p^2_C.$$
$$p'_A = 66.3 + 0.15 \cdot p_C - 0.004 \cdot p^2_C.$$
$$p''_A = 74.9 - 0.017 \cdot p_C{}^2.$$

$$\Sigma p/d = \Sigma(a \cdot p + b \cdot p^2), \qquad (14)$$

wherein p = weight percentage of any constituent.
d = density of glass.
a and b = constants.

SiO_2 in soda-silica glasses was assigned the density of vitreous SiO_2 ($= 2.303 = 1/a$; $b = 0$). A plot of apparent (called "partial" by Gilard and Dubrul) volume of Na_2O against percentage of Na_2O produced a parabolic curve which could be expressed by

$$v'_B = (a \cdot p_B + b \cdot p^2_B),$$

wherein v'_B = apparent volume contribution of p_B(% of Na_2O).

From these constants for silica and soda, the apparent volumes and coefficients of other oxides were derived (Table V).

The introduction of a squared term in their equation resulted in greater accuracy than had previously been obtained. The types of glass in which the constants are valid were not mentioned.

Young, Glaze, Faick, and Finn[25] determined the densities of 194 reproducibly annealed, analyzed glasses in the ternary system Na_2O–K_2O–SiO_2. To determine the relation between specific volume and composition, a triordinate diagram was prepared in which the trend and separation of the lines of constant v (specific volume) divided the surface into several relatively flat regions of different slopes. Each region was treated arbitrarily as a plane of the form in equation (15).

$$v = a \cdot p_A + b \cdot p_B + c \cdot p_E, \qquad (15)$$

wherein p_A, p_B, and p_E = respective weight percentages of SiO_2, Na_2O, and K_2O.
Constants a, b, and c were evaluated for each region (Table VI).

In contradiction to their previously published results, the intersections of the planes in the three-dimensional triordinate diagram were found to correspond to boundary curves and eutectic compositions in the equilibrium diagrams of Kracek. Agreement was good for soda-silica and potash-silica data but only approximate for glasses containing all three constituents.

(A) Significance of "Density Constants": A recapitulation reveals that all of the "factors" or "constants" mentioned thus far were so derived as to fit mathematically calculated and observed values. These empirical evaluations were based on the apparently incorrect assumption that the density of SiO_2 in glass is constant or the same as that of vitreous SiO_2 throughout the whole range of composition.

The similarity of glass and concentrated aqueous ionic solutions suggested the use of partial molal (or partial specific) quantities to represent true oxide contributions to the properties of glass. A calculation of the partial specific volumes* of SiO_2, Na_2O, and K_2O (method II of Lewis and Randall[26]) from the density

[25] J. C. Young, F. W. Glaze, C. A. Faick, and A. N. Finn, "Density of Some Soda-Potash-Silica Glasses as a Function of the Composition," *Jour. Research Nat. Bur. Stand.*, **22** [4] 453–64 (1939); *Ceram. Abs.*, **18** [9] 237 (1939).

* Partial specific volume equals partial molal volume divided by molecular weight.

[26] G. N. Lewis and M. Randall, Thermodynamics, chapters IV and VIII. McGraw-Hill Book Co., New York, N. Y., 1923.

TABLE V

DENSITY CONSTANTS AFTER GILARD AND DUBRUL[24]

Oxides	$(a \cdot p + b \cdot p^2)$	Limits	Errors (%)
Li_2O	$0.320 \cdot p$	$p < 15$	0.5
Na_2O	$0.286 \cdot p$	$p < 20$	0.4
	$0.286 \cdot p + 0.0022\ (p - 20)^2$	$20 < p < 50$	0.4
K_2O	$0.333 \cdot p$	$p < 30$	1.5
Rb_2O	$0.225 \cdot p$	$p < 15$	0.5
BeO	$0.195 \cdot p + 0.009 \cdot p^2$	$p < 15$	1.0
MgO	$0.250 \cdot p + 0.004 \cdot p^2$	$p < 15$	0.5
CaO	$0.175 \cdot p + 0.002 \cdot p^2$	$p < 40$; p (Na_2O) < 20	1.0
	$0.200 \cdot p + 0.004 \cdot p^2$	$p < 25$; p (Na_2O) > 20	1.0
BaO	$0.100 \cdot p + 0.001 \cdot p^2$	$p < 40$	1.5
ZnO	$0.160 \cdot p$	$p < 30$	1.0
PbO	$0.092 \cdot p$	$p < 80$	1.5
MnO	$0.250 \cdot p$	$p < 20$	
B_2O_3	$0.550 \cdot p$	$35 < p < 100$, (SiO_2-B_2O_3)	1.0
	$0.390 \cdot p + 0.0016 \cdot p^2$	$70 < p < 100$, (Na_2O-B_2O_3)	2.0
		$p < 30$, (SiO_2-B_2O_3-Na_2O)	
	$0.290 \cdot p + 0.0026 \cdot p^2$	$p < 40$, (complex glasses)	2.0
Al_2O_3	$0.390 \cdot p$	p 25	1.5
Bi_2O_3	$0.096 \cdot p$	$p < 55$	1.0
Fe_2O_3	$0.136 \cdot p + 0.004 \cdot p^2$	p 30	0.75
SiO_2	$0.454 \cdot p$	p: 0–100	
GeO_2	$0.215 \cdot p + 0.0006 \cdot p^2$	$60 < p < 100$	
TiO_2	$0.150 \cdot p + 0.007 \cdot p^2$	$p < 10$	0.3
ZrO_2	$0.150 \cdot p + 0.0025 \cdot p^2$	$p < 20$	1.0

data of Finn and others[25] revealed that the constants in Table VI are actually thermodynamic partial specific volumes. Their procedure for evaluation is identical with method IV of Lewis and Randall.[26] These partial quantities are constant for rather wide ranges of composition, whereas in aqueous solution similar quantities vary continuously with concentration.

Geffcken[27] has reported calculations of partial molal refractions for the components of B_2O_3-Na_2O glasses.

(2) Compound Factors

Day and Allen,[28] Larsen,[29] Wallace,[30] and Tillotson[31] favored concepts of compound formation. Larsen and Tillotson obtained linear density-composition graphs for the albite-anorthite glasses of Day and Allen. A similar plot for the $CaSiO_3$-$MgSiO_3$ glasses of Larsen led Tillotson to attribute two breaks in the curve to the presence of $CaMg_3(SiO_2)_4$ and $Ca_4Mg(SiO_2)_5$. Curve deflections, observed in his own researches, led him to conclude that the following compounds exist in glass at room temperature: $Na_2O \cdot 2SiO_2$, $BaO \cdot 2SiO_2$, $Na_2O \cdot BaO \cdot 3SiO_2$, $Na_2O \cdot BaO \cdot 4SiO_2$, and $2Na_2O \cdot 3CaO \cdot 7SiO_2$.

Karmaus[32] prepared eight series of lead glasses of the general formula $a(PbO \cdot SiO_2) \cdot (10-a)$ (B), wherein a varied from 1 to 10 and B represented one of the following expressions: $(K_2O \cdot 6SiO_2)$, $(Na_2O \cdot 6SiO_2)$, $((\frac{1}{2}K_2O + \frac{1}{2}Na_2O) \cdot 6SiO_2)$, $(K_2O \cdot 5.5SiO_2 \cdot \frac{1}{2}Al_2O_3)$, $(K_2O \cdot 5.8SiO_2 \cdot 0.2Al_2O_3)$, or $(K_2O \cdot 4SiO_2 \cdot 2B_2O_3)$, $(K_2O \cdot 4SiO_2)$, $(K_2O \cdot 8SiO_2)$. Densities for these glasses were computed from the re-arranged additive formula (equation (16)).

$$d = \frac{a \cdot d_B(a \cdot M_A + (10 - a)\, M_B)}{a \cdot d_B \cdot M_A + (10 - a) d_A \cdot M_A}, \qquad (16)$$

wherein d_A = measured density of $PbO \cdot SiO_2$.
d_B = that for B (Table VII).
M_A and M_B = respective molecular weights.

When B represented $(K_2O \cdot 6SiO_2)$, $(Na_2O \cdot 6SiO_2)$, $(K_2O \cdot 4SiO_2 \cdot 2B_2O_3)$, and $(K_2O \cdot 8SiO_2)$, a 0.2 to 0.6% average deviation between calculated and experimental values resulted.

Scholes[33] analyzed a number of commercial soda-lime-magnesia-silica glasses and converted oxide percentages into equivalent percentages of $Na_2O \cdot 2SiO_2$, $CaSiO_3$, $MgSiO_3$, Al_2O_3, and SiO_2. From Baillie's factors for silica and Al_2O_3 (Table I), the following constants were derived:

$$Na_2O \cdot 2SiO_2 = 2.483. \quad CaSiO_3 = 2.992. \quad MgSiO_3 = 2.714.$$

Densities from these values were more accurate than calculations involving oxide factors.

Biltz and Weibke[34] believed that technical glasses were composed of the following silicates: Na_2SiO_3, $Na_2Si_2O_5$, $K_2Si_2O_5$, $K_2Si_4O_9$, Li_2SiO_3, $MgSiO_3$, $CaSiO_3$,

[27] W. Geffcken, "Molecular Refraction in Glasses," *Glastech. Ber.*, **17** [8] 237–40 (1939); *Ceram. Abs.*, **19** [1] 9 (1940).

[28] A. L. Day and E. T. Allen, "Isomorphism and Thermal Properties of Feldspars," *Amer. Jour. Sci.*, [4] **169** [19] 93–142 (1905).

[29] E. S. Larsen, "Relation Between Refractive Index and Density of Some Crystallized Silicates and Their Glasses," *ibid.*, [4] **178** [28] 263–74 (1909).

[30] R. C. Wallace, "Binary Systems Sodium Metasilicate with Lithium, Magnesium, Calcium, Strontium, and Barium Metasilicates; and Lithium Metasilicate with Potassium, Magnesium, Calcium, Strontium, and Barium Metasilicates; and on the Ternary System Na_2O–Al_2O_3–SiO_2," *Z. anorg. allgem. Chem.*, **63** [1] 1–48 (1909).

[31] (*a*) E. W. Tillotson, Jr., "Relation of Refractive Index of Soda-Barium and Soda-Lime Glasses to Their Chemical Composition," *Jour. Ind. Eng. Chem.*, **4** [12] 882–85 (1912).
(*b*) E. W. Tillotson, Jr., "Relation Between Physical Properties and Chemical Composition of Glass: VIII, Molecular Compounds," *Jour. Amer. Ceram. Soc.*, **1** [2] 76–93 (1918).

[32] H. Karmaus, "Studies on Some Chemical and Physical Properties of Lead Glasses as Functions of Their Composition," *Sprechsaal*, **59**, 725, 747, 768 (1926); *Ceram. Abs.*, **6** [8] 336 (1927).

[33] S. R. Scholes, "Density Factors for Soda-Lime Glass," *Jour. Amer. Ceram. Soc.*, **12** [12] 753–55 (1929).

[34] (*a*) W. Biltz and F. Weibke, "Calculating Densities of Glasses, No. 39," *Z. anorg. allgem. Chem.*, **203** [3] 345–64 (1932); *Ceram. Abs.*, **11** [6] 390 (1932); abstracted in *Sprechsaal*, **64** [47] 867 (1931); *Ceram. Abs.*, **11** [9] 506 (1932).
(*b*) W. Biltz and F. Weibke, "Calculation of Densities of Glass, No. 40," *Glastech. Ber.*, **10** [10] 577–93 (1932); *Ceram. Abs.*, **11** [2] 89 (1932).

TABLE VI

NUMERICAL VALUE OF CONSTANTS* FOR DIFFERENT REGIONS AFTER YOUNG, GLAZE, FAICK, AND FINN[25]

Constant × 100	Region							
	1	2	3	4	5	6	7	8
a	0.428 00	0.437 10	0.454 00	0.441 05	0.448 35	0.441 65	0.447 85	0.454 00
b	0.348 60	0.332 65	0.282 95	0.320 55	0.299 60	0.290 85	0.273 20	0.265 15
c	0.358 90	0.339 15	0.308 00	0.350 75	0.334 00	0.356 25	0.342 50	0.322 85

* These constants are actually partial specific volumes.

TABLE VII

DENSITY FACTORS AFTER KARMAUS[32]

	Measured values					
$PbO \cdot SiO_2$	5.808	$K_2O \cdot 6SiO_2$	2.353	$Na_2O \cdot 6SiO_2$	2.393
$K_2O \cdot 4SiO_2 \cdot 2B_2O_3$	2.360	$K_2O \cdot 8SiO_2$	2.319	$K_2O \cdot 4SiO_2$	2.337

Ca_2SiO_4, $BaSiO_3$, $BaSi_2O_5$, $Ba_2Si_3O_8$, Zn_2SiO_4, $PbSiO_3$, Be_2SiO_4, and $MnSiO_3$. Observed and calculated volumes for any glass were expressed by equations (17) and (18).

$$V_{observed} = \frac{\Sigma P \cdot M}{100 \cdot d}, \quad (17)$$

$$V_{calculated} = \frac{\Sigma P' \cdot v'}{100}. \quad (18)$$

wherein V = molecular vol. of glass.
P = mole per cent of constituent oxide.
M = molecular weight of same oxide.
d = observed density of glass.
P' = mole per cent of a constituent silicate.
v' = equivalent vol. of same silicate.*

* Equivalent volume (as defined by Biltz and Weibke) is the experimental volume of any silicate divided by the number of moles of simple oxides contained in the silicate.

Equivalent volumes for their silicates (Table VIII) were obtained from composition and density data for 400 glasses reported in the literature. They claimed 0.5% accuracy for their calculated densities.

Biltz, Weibke, and Schrader-Traeger[35] revised certain volume constants (Table VIII) and calculated molecular volumes for a number of soda-silica, soda-lime-silica, soda-alumina-silica, and soda-boric oxide glasses, the average errors ranging from 0.25 to 0.63%. Molecular volumes of soda-silica glasses, plotted against mole per cent of SiO_2, resulted respectively in continuous and linear curves of two segments for measured and calculated values. Empirical constants, derived from the equivalent volumes for Na_2SiO_3 and $Na_2Si_2O_5$, were applied to produce each segment. Oxide factors as normally used would yield less accurate results, as a single constant would necessarily cover the whole range of composition. It should be emphasized that a conversion of the foregoing silicate factors into corresponding oxide constants would not alter the accuracy of calculation. Criticism by Knapp[36] was satisfactorily answered by Biltz and his associates.[37]

Knapp[38] assumed that the presence of a particular silicate in soda-silicate glasses was dependent on total silica content, mono-, di-, tri-, and tetra-silicates existing over the respective ranges 50–67, 67–75, 75–80, and more than 80% of SiO_2. His volume constants are shown in Table IX.

[35] W. Biltz, F. Weibke, and L. Schrader-Traeger, "Molecular Refractions and Molecular Volumes of Glasses," *Z. anorg. allgem. Chem.*, **234**, 253 (1937); condensed article in *Glastech. Ber.*, **16** [4] 131–33 (1938); *Ceram. Abs.*, **17** [10] 326 (1938).

[36] (*a*) O. Knapp, "Constitution of Silicate Glasses on Basis of Biltz-Weibke Hypothesis," *Keram. Rundschau*, **43** [36] 423–24 (1935); *Ceram. Abs.*, **15** [11] 346 (1936).

(*b*) O. Knapp, "Molecular Volumes of Glasses," *Keram. Rundschau*, **46** [21] 231–34 (1938); *Ceram. Abs.*, **18** [1] 17 (1939).

[37] W. Biltz and F. Weibke, "Molecular Volumes of Glasses," *Keram. Rundschau*, **46** [51] 600 (1938); *Ceram. Abs.*, **18** [9] 239 (1939).

[38] (*a*) O. Knapp, "Calculation of Volumes for Soda-Boric Oxide-Silica Glasses," *Keram. Rundschau*, **40**, 659–62, 673–75 (1932).

(*b*) O. Knapp, "Constitution of Glass Based on Laws of Solution," *Jour. Soc. Glass Tech.*, **15** [58] 140–52 (1931); *Ceram. Abs.*, **10** [10] 683 (1931).

TABLE VIII

EQUIVALENT VOLUME AND DENSITY OF GLASSY SILICATES AFTER BILTZ, WEIBKE, AND SCHRADER-TRAEGER[35]

	Values published 1933		Values revised 1937
	Eq. vol.	Density	Eq. vol.
Na_2SiO_3	23.8	2.560	23.74
$Na_2Si_2O_5$	24.4	2.492	24.40
$K_2Si_2O_5$	29.1	2.457	28.88
$K_2Si_4O_9$	27.9	2.400	27.87
Li_2SiO_3	17.3	2.61	
$MgSiO_3$	18.2	2.750	
$CaSiO_3$	20.0	2.91	
Ca_2SiO_4	(18)	3.19	
$BaSiO_3$	24.1	4.44	
$BaSi_2O_5$	(24)	3.80	
$Ba_2Si_3O_8$	(24)		
Zn_2SiO_4	18.7	3.980	
$PbSiO_3$	24.3	5.835	24.27
$MnSiO_3$	18.8	3.48	
Be_2SiO_4	(12.7)		
$Na_2B_4O_7$			28.23
B_2O_3	37.7	1.84	36.91
SiO_2	27.3	2.206	27.25

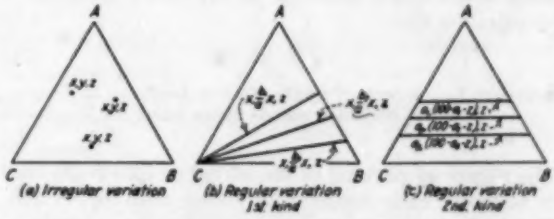

FIG. 1.—Composition variations in ternary systems (for reference, see p. 325).

For soda-boric oxide-silica glasses, specific volumes were calculated on the assumption that combinations of double molecules were possible. Total glass volume, V, was calculated according to the linear additive formula, equation (19).

$$V = m_A \cdot V_A + m_B \cdot V_B + \ldots\ldots \quad (19)$$

wherein m_A, m_B = silicate constituents and free SiO_2 (mole).
V_A, V_B = their respective molar vol. constants.

TABLE IX

VOLUME CONSTANTS FOR GLASSY SILICATES AFTER KNAPP[38]

	Monosilicates	Disilicates	Trisilicates
Na silicate	39.0	40.15	41.25
Borosilicate	34.1	52.8	
Na borosilicate	37.8	39.0	39.6
B_2O_3		44.1	
SiO_2		42.4	

Knapp's results from sixteen Na_2O-B_2O_3-SiO_2 glasses showed a mean deviation between experimental and calculated values of 0.68%, as compared with 4.6, 2.9, and 5.5%, respectively, using the Schott, Tillotson, and Baillie factors.

Bary and Herbert[39] calculated density constants from four soda-lime-silica glasses by considering the glass as a frozen product, formed of dissolved alkali-silicates in alkali-earth polysilicates and the silica to be present in two distinct forms, "crystalloidal" and "vitreous." The scope of the work renders their results unreliable.

(3) Single Atom or Ion Factors

Randall and Gee[40] introduced the following method for the calculation of density.

Volume per molecule of glass (in cubic Angstroms) is given in equation (20).

$$V_m = \frac{M(10^8)^3}{d \cdot 6.06 \times 10^{23}} = 1.66 \cdot M/d \text{ Å}^3, \qquad (20)$$

wherein M = molecular weight.
d = density of glass.

Using the values of atomic sizes found for crystalline silicates (Bragg[41] has indicated such sizes to be fairly constant), Randall and Gee found V_m for glass to bear an almost constant ratio to the sum of the volumes of the atoms in the molecule, which is expressed by equation (21).

$$V_m = k\Sigma V_a, \qquad (21)$$

wherein V_a = vol. of single atom or ion.
k = constant whose mean value for 28 glasses is 2.065.

The degree of packing of the atoms or ions was found to be more nearly constant for glasses than for crystals. The ionic diameters used in calculation are as follows:

Ions	O^{--}	Si^{4+}	Na^{+}	K^{+}	Ca^{++}	Pb^{++}	B^{+++}
Diameters	2.70	0.6	2.0	2.6	2.0	2.5	0.4

The maximum divergence of 5% from k equals 2.065 limits the practicability of the method. This constant was found to be larger for glasses than for crystals because the latter are usually more dense than glasses.

Analogies to these studies of volume and density of glass should be mentioned. Biltz and Lemke[42] measured the density of crystalline silicates of Na, Li, Zn, Cd, Mn, Pb, Be, Ca, Sr, Ba, Mg, Fe, Ni, and Zr and calculated the volume of the oxygen ion in these compounds by the formula in equation (22).

$$V_{oxygen} = (V_{silicate} - V_{metallic\ oxide})/m, \qquad (22)$$

wherein m = twice the number of Si atoms present.

It was assumed that the volume of the Si atom is negligible. Relative V_{oxygen} values thus calculated were 11.0, 11.1, 10.9, and 11.6, respectively, for ortho-, meta-, double, and all other types of silicates, and 11.35 for α-quartz. The atomic volume for elementary oxygen in its normal form was reported as 10.9, indicating the validity of the assumption as well as the constancy of the values in various crystals.

Warren and Loring[43] and Warren and Biscoe[44] differentiate two types of oxygen ions in glass. The one, sometimes classified as "frame" or "structure" oxygen, joins two Si ions; the other, called "anion" oxygen joins a Si ion and an alkali or metallic ion. Following their method for crystalline silicates, Biltz and others[35] calculated volumes for oxygen ions in glass. Their results indicated that the volume of "frame" oxygen in soda-silica glasses agrees well with that for potash-silica glasses, whereas the volume of "anion" oxygen decreases as the diameter of binding alkali ions increases.

Density of crystalline substances may be accurately calculated from X-ray measurements of interionic distances.[45] Warren and others[14] have recently made similar studies of amorphous materials. It will be recalled that Turner (see page 317), on plotting density-percentage B_2O_3 curves for soda-boric oxide-silica glasses, observed a maximum and minimum, respectively, for the two series studied, whereas the curve for boric oxide-silica glasses was linear. Warren pointed out that in the presence of alkali oxides, boron ions are able to assume tetrahedral coordination, forming compact structures of increased density. As soon as the unbound oxygen from soda has been used up, further addition of B_2O_3 produces no change, density starts to decrease, and a maximum is formed. In the case of boric oxide-silica glasses, there is no unbound oxygen, the boron is unable to assume a tetrahedral coordination, and no maxima or minima appear. Warren's explanation does not seem to be applicable to the formation of minima. A calculation of density from X-ray data for the glass, $Na_2O \cdot 5B_2O_3$, is illustrated in the following example (after Warren and Biscoe).[14(a)]

The molecular formula was arbitrarily split into two components, $Na_2B_2O_4$ and $4B_2O_3$. In $Na_2B_2O_4$, the oxygen-boron ratio is 2.00, and all of the boron ions were supposed to be in tetrahedral coordination with sodium ions in the network holes. From the assumption that the structure of $Na_2B_2O_4$ is the same as that of vitreous silica except that the respective bond distances for B-O and Si-O are 1.50 Å and 1.62 Å, the density of this hypothetical glass, $Na_2B_2O_4$, was obtained from the following equation:

$$d = 2.20 \times \frac{M/(1.50)^3}{M'/(1.62)^3} = 3.04,$$

wherein 2.20 = density of vitreous silica.
M = molecular weight of $Na_2B_2O_4$.
M' = molecular weight of $2SiO_2$.

[39] P. Bary and J. Herbert, "Determination of Density of Glasses by Law of Addition," *Compt. Rend.*, **207** [15] 627–29 (1938); *Ceram. Abs.*, **18** [2] 46 (1939).

[40] J. T. Randall and N. Gee, "Refractive Index, Atomic Size, and Packing in Glasses," *Jour. Soc. Glass Tech.*, **15** [57] 41–53 (1931); *Ceram. Abs.*, **10** [8] 552 (1931).

[41](a) W. L. Bragg, Structure of Silicates. Academic Publishing Society, Leipzig, 1930; *Ceram. Abs.*, **10** [1] 73 (1931).

(b) W. L. Bragg, Atomic Structure of Minerals. Cornell Univ. Press, Ithaca, N. Y., 1937; *Ceram. Abs.*, **17** [6] 231 (1938).

[42] W. Biltz and A. Lemke, "Volumes of Some Silicates, No. 38," *Z. Anorg. Allgem. Chem.*, **203** [3] 330–34 (1932); *Ceram. Abs.*, **11** [6] 390 (1932).

[43] B. E. Warren and A. D. Loring, "X-Ray Diffraction Study of Structure of Soda-Silica Glass," *Jour. Amer. Ceram. Soc.*, **18** [9] 269–76 (1935).

[44] B. E. Warren and J. Biscoe, "Fourier Analysis of X-ray Patterns of Soda-Silica Glass," *ibid.*, **21** [7] 259–65 (1938).

[45] W. P. Davey, Study of Crystal Structure and Its Applications, p. 35. McGraw-Hill Book Co., New York, N. Y., 635 pp., 1934; *Ceram. Abs.*, **14** [2] 51 (1934).

The composition of $Na_2O \cdot 5B_2O_3$ is 32.1% of $Na_2B_2O_4$ and 67.9% by weight of B_2O_3. Assuming linear additivity, the density of $Na_2O \cdot 5B_2O_3$ was calculated to be 2.11. Warren and Biscoe concluded that although the calculation was based on highly idealized assumptions the value was of the right order of magnitude.

For the same system, Na_2O–B_2O_3, Kordes[46] found good agreement between measured and calculated values of molecular volume for additions of 0 to 10 mol per cent of Na_2O. He assumed that, for these low concentrations of Na_2O, the addition of this oxide merely results in a filling of the gaps of the original boric oxide glass, that is, not only the Na atoms but also the O atom from Na_2O, which enters as the fourth coordination atom for boron, occupy empty holes in the basic glass.

Kordes also introduced an interesting method for the calculation of the molecular volume of glass from ionic radii and the molecular volume of vitreous silica. For Na_2O-SiO_2 glass, he used the following formula:

$$V = V_S \cdot \left[\frac{x_S + 1}{2}\right] \cdot \left[\frac{\Sigma x r^3(O^{Si}, O^{Si-Na}, Na)}{2r^3O^{Si}}\right]^*,$$

wherein V and V_S = vol. per mol of glass and vitreous silica, respectively.
x_S = mol fraction of SiO_2 in glass.
$\frac{x_S+1}{2}$ = ratio of number of oxygens in glass to that in vitreous silica; second factor in brackets = ratio of vol. of different kinds of atoms in glass to that of O atoms in SiO_2 glass.
x = number of equivalents of particular atom in one mol of glass.
r = radius of that atom.
O^{Si} = that kind of oxygen connected to Si atoms alone.
O^{Si-Na} = that type of oxygen linked between Si and Na atoms.

* The reviewers have changed the form of this equation to make it more understandable; its original meaning is intact.

The volume of the Si atom has been neglected for it just fills the gaps between the oxygen atoms because of its small size.

The radii of the O^{Si} and Na atoms were known and those of O^{Si-Na} were obtained from ionic refractivities.

Kordes[47] developed the following equation, empirically, which affords a calculation of ionic radii from ionic refractivities:

$$r = \frac{1}{z^{2/(n-1)}} \cdot \left[\sqrt[3]{\frac{K}{0.603}}\right]^{2/3}$$

wherein r = ionic radius in Å.
z = valence.
K = ionic refractivity.
n = Born's repulsion constant.

Values calculated by the foregoing formula checked well with the experimental curves of Finn and others up to 24 mol per cent of Na_2O. The same type equation, applied to the system PbO–SiO_2, held up to 30 mol per cent of PbO. Calculations by a similar formula for the system P_2O_5–PbO agreed well with experimental curves from 0 to 90 mol per cent of PbO. Such considerations involving ionic radii and ionic refractivities are significant in future developments in this field.

The apparent conclusion reached thus far is that it is immaterial whether oxide, compound, or atom or ion factors are used for density calculations, provided good agreement between measured and calculated values is obtained. Modern ideas of glass constitution trend toward the concept of Warren and Zachariasen[48] that glasses containing silica are a nonrepeating and nonsymmetrical network of ions whose fundamental unit is the tetrahedral SiO_4 structure.

(B) Treatment by Masson's Empirical Solution Law

Masson,[49] for twenty-eight cases of aqueous solution, disclosed a linear relationship between apparent volume of solute and the square root of the solute concentration expressed in gram-moles per liter of solution.

Scott[50] found Masson's relation valid for many ions in aqueous solution. Waterton,[51] considering glass to be a supercooled or solidified solution, applied equation (23) of Masson-Scott to soda-silica and boric oxide-silica glasses.

$$\phi = \alpha \cdot m^{1/2} + \beta, \qquad (23)$$

wherein ϕ = apparent molal vol.* of solute.
m = concentration in moles/liter of solution.
α and β = constants for each solution at a definite temperature.

* ϕ may be defined by $\phi = \frac{V - m_1 \cdot V_1}{m_2}$,

wherein V = vol. of solution.
V_1 = vol. of 1 mole of solvent in pure state.
m_1 = number of moles of solvent.
m_2 = number of moles of solute.

Waterton, who considered Na_2SiO_3 to be a solute and SiO_2 a solvent, took values for density from the smooth curve of Winks and Turner and applied equation (24), the modified form of equation (23).

$$\left(\frac{v - x \cdot v_s}{y^2}\right) = \alpha(y/v)^{1/2} + \beta, \qquad (24)$$

wherein v = specific vol. of glass.
v_s = specific vol. of vitreous SiO_2 (2.19).
y = wt. fraction of Na_2SiO_3.
x = wt. fraction of SiO_2.

Let the functions in parentheses be represented by (A) and (B), respectively.

[46] Ernst Kordes, "Physicochemical Investigation of Fine Structure of Glasses, II," *Z. physik. Chem.*, **B43**, 119–52 (1939); *Ceram. Abs.*, **19** [1] 10 (1940).

[47] Ernst Kordes, "Determination of Atomic Distances from Refraction," *Z. physik. Chem.*, **B44** [4] 249–60 (1939); [5–6] 327–43 (1939).

[48] G. W. Morey, Properties of Glass, chapter XX, pp. 518–39; discussion of work by Warren and Zachariasen. American Chemical Monograph Series, Reinhold Publishing Corp., New York, N. Y., 1938. 561 pp.; *Ceram. Abs.*, **18** [2] 48 (1939).

[49] D. O. Masson, "Solute Molecular Volumes in Relation to Solvation and Ionization," *Phil. Mag.*, [7] **274** [8] 218–35 (1929).

[50] A. F. Scott, "Apparent Volumes of Salts in Solution," *Jour. Phys. Chem.*, **35**, 2315–29 (1931).

[51] S. C. Waterton, "Specific Volumes of Some Two-Component Glasses," *Jour. Soc. Glass Tech.*, **15** [60] 354–60 (1931); *Ceram. Abs.*, **11** [7] 405 (1932).

For aqueous solutions, the graph of (A) against (B) is a straight line, whereas the plot for the soda-silica glasses indicates three straight lines. This observation compares favorably with the specific volume-percentage SiO_2 curves of Finn. Waterton suggested correspondence of his curve breaks to the compounds $Na_2O \cdot 4SiO_2$ (20.53% of Na_2O) and $Na_2O \cdot 2SiO_2$ (34.07% of Na_2O) as compared with Finn's graphic intersections at 25 and 37% of Na_2O.

Morey and Merwin[52] pointed out that Waterton's recalculation of weight-percentage data for Na_2O and SiO_2 to like data for Na_2SiO_3 and SiO_2 was unnecessary as linear relations (equations (23) or (24)) are not affected by such computations. Upon the application of equation (24) to their own data, Morey and Merwin found no justification for breaking the continuous curve into straight-line segments.

For the boric oxide-silica glasses of Cousen and Turner, Waterton considered SiO_2 as a solute and B_2O_3 as a solvent. The graph of (A) against (B), equation (24), produced two straight lines whose intersection corresponded roughly to the composition $B_2O_3 \cdot SiO_2$, suggesting to Waterton its presence in the glass.

Had he evaluated α and β, specific volumes for other compositions could be calculated.

The reviewers, from Finn's equation, $v = a \cdot p_A + \cdots b \cdot p_B$ (p. 319) for soda-silica glasses, and equation (23), formulated equation (25).

$$\left[\frac{a' - v_s}{y'} + b' - a' + v_s\right] = \alpha_1 \left[\frac{y'}{a' + (b' - a') \cdot y'}\right]^{1/2} + \beta_1, \quad (25)$$

wherein $a' = 100 \cdot a$.
$b' = 100 \cdot b$.
v_s = specific vol. of vitreous silica.
y' = weight fraction of Na_2O (not Na_2SiO_3).
α_1 and β_1 = constants.

Let the functions in brackets be represented respectively by A' and B'. If the Masson-Scott law holds for binary glasses, a plot of A' against B' should produce a straight line. A mathematical consideration of equation (25) indicates that a strict linear relation is impossible.

The writers have plotted A' against B', using three sets of values of a' and b' (from Finn's data, Table VI) for three ranges of y', 0 to 0.25, 0.25 to 0.37, and 0.37 to 0.50. For the first limit, because $a' = v_s$, the graph was horizontal, whereas for the second and third ranges (corresponding to 50 to 75% of SiO_2), two curves were obtained wherein the mean deviation of A' from a straight line did not exceed 0.08%.

Values for A' and B' from direct calculation of the experimental data of Finn[25] were also graphed. The first break, at 25% of Na_2O, is marked, whereas the second break mentioned both by Waterton and Finn is insignificant.

Masson's law apparently is valid when it is applied to soda-silica glasses and enables calculations of density from composition to be made. Close similarity between glass and aqueous solution is indicated. It is extremely interesting that this empirical equation holds for solute-solvent ratios of nearly 1:1 in glass, whereas in aqueous solution its application is limited to much lower concentrations.

(C) Graphic Representation

Graphic representation affords a convenient and clearly understandable method for the presentation of experimental data.

Lines or planes representing identical values of density, specific volume, or refractive index against composition are termed "isoproperty" curves. Finn and others,[53] in studies of soda-lime-silica glasses, have pointed out that for the same system, although certain glasses may have the same density and other glasses identical refractive indices, there can be but one glass representing a given density and refractive index. Consequently if one knows the refractive index and density for any glass of a series, its composition is indicated with fair accuracy by the point at which its density and refractive index lines intercept.

A discussion of (1) correct expressions of composition, (2) suitable choice of properties to be plotted, and (3) graphic representation for poly-component systems should clarify some of the confusion extant in the literature.

(1) Correct Expressions of Composition

TABLE X

METHOD FOR EXPRESSING COMPOSITION

Volume basis		Percentages Representative numbers*
Mass basis	Mole	Percentages Representative numbers*
	Weight basis	Percentages Representative numbers*

* The term "representative numbers" implies parts by weight, parts by volume, and similar expressions based on composition totals other than 100.

Because a volume basis is seldom used, attention is centered about composition in terms of mass.

In a graph of volume against composition, if the composition is expressed in percentage by weight, by mole percentage, or by representative numbers, the corresponding properties to be plotted should be, respectively, specific volume, molecular volume, or total volume. A graph, for example, of specific volume against mole percentage is without meaning.

Whether mole volume and mole percentage or specific volume and weight percentage are used, mathematical considerations indicate that a linear relation holding for the first case will likewise prove valid in the second.

[52] G. W. Morey and H. E. Merwin, "Relation Between Composition and Density and the Optical Properties of Glass: I, Soda-Lime-Silica Glasses," *Jour. Optical Soc. Amer.*, **22**, 632–62 (1932); p. 656; *Ceram. Abs.*, **12** [6] 218 (1933).

[53] "Research Work in Glass Industry Reported by Bureau of Standards," *Ceram. Ind.*, **18** [2] 92–97 (1932).

TABLE XI

COMPOSITION VARIATIONS IN TERNARY SYSTEMS (for triaxial diagrams, see p. 321)

Expression of composition		Representative Nos.*			(%)		
Components		*A* :	*B* :	*C*	*A* :	*B* :	*C*
Irregular variation†		s'	u'	w'			
	or				x	y	z (Fig. 1(*a*))
		a	u	w			
Regular variation†	1st kind	a	$\underline{b}$	w	x	$(\underline{b}/a)x$	z (Fig. 1(*b*))
	2nd kind	$\underline{a}'$	$(b\text{-}\underline{a}'\text{-}w')$	w'			
		or multiplying each by $\frac{100}{b}$					
		$\underline{a}$	$(100\text{-}\underline{a}\text{-}w)$	w	$\underline{a}$	$(100\text{-}\underline{a}\text{-}z)$	z (Fig. 1(*c*))

* See star (*) footnote in Table X.

† $s, u(u'), w(w')$ = variables.
x, y, z = variables; $x + y + z = 100$.
a and b = constants for all series in a system.
$\underline{a}$, $(\underline{a}')$, and $\underline{b}$ = constants for one series only which vary from series to series in the same system.

The same argument is not applicable to such unitless properties as refractive index; in these instances, it is difficult to choose a correct composition expression.

(2) Suitable Choice of Properties to Be Plotted

For a property-composition graph, it is convenient so to choose the variables that a simple physical conception, approximating the phenomenon involved, is represented by a simple curve. Glass technologists have long recognized that it is specific volume and not density that is a linearly additive function. It should be remembered that, for binary systems, a straight-line relation between specific volume and weight percentage does not require that a linear graph result from a plot of density against weight percentage.

(3) Graphic Representation for Poly-Component Systems

The often-used expression in equation (26) is not basic and may be derived from the fundamental equation (27),

$$V = P_A \cdot V_A + P_B \cdot V_B + \ldots\ldots \quad (26)$$

$$V' = m_A \cdot V_A + m_B \cdot V_B + \ldots\ldots \quad (27)$$

wherein V = mole vol. of glass.
P_A and P_B = mole percentages.
m_A and m_B = number of moles of components A and B.
V_A and V_B = their respective mole-vol. factors.
V' = total vol. of glass.

As P_A of equation (26) is equivalent to $m_A/(m_A + m_B + \ldots)$ for equation (27), the former is not a simple variable, and mathematical treatment of equation (26) is difficult.

Partial differentiation of equation (27) with respect to m_A obtains in equation (28).

$$\overline{V}_A = \frac{\partial V'}{\partial m_A}, \quad (28)$$

wherein $\overline{V}_A$ = partial molal vol. of A.

A series of glasses is considered of the general composition, $xA \cdot bB \cdot cC \ldots\ldots$, wherein x is any number, and $b, c, \ldots$ are kept constant.* A straight line resulting from plotting V' against x, renders the linear-addition relationship valid as far as glass constituent A is concerned. It is obvious that discussions of property-percentage composition curves for poly-component systems are complicated and have little significance. The situation for a binary or ternary system is somewhat simpler.

(*A*) *Binary System:* For a binary system, there is but one variable because the number or percentage of one of the components may be fixed. Straight lines resulting from property-composition plots for such systems indicate the validity of linear relationships. For such cases, compositions may be simply expressed, either by relative numbers or by weight or mole percentages.

(*B*) *Ternary Systems:* Table XI lists the possibilities for variation of composition in ternary systems.

Because there are but two independent variables for three-component systems, it is possible, as Zschimmer[44] suggests, to express compositions on two-dimensional coordinate graphs. The reviewers, however, prefer the use of triaxial plots for reasons of symmetry and direct reading of the three-component compositions.

Graphic illustrations for composition-variations in ternary systems are shown in Fig. 1, p. 321. For triaxial diagrams, compositions should be expressed on a percentage basis.

(i) *Irregular Variation:* For such composition expressions, Morey and Merwin as well as other authors have adopted the method of plotting isoproperty lines on triaxial diagrams. Along any isoproperty line, composition changes continuously, whereas the property

* Partial differentiation requires that this be so.

[44] (*a*) E. Zschimmer, "Theory of Composition of Glass," *Jour. Soc. Glass Tech.*, **14** [55] 229–49 (1930); *Ceram. Abs.*, **10** [5] 335 (1931).
(*b*) E. Zschimmer, "Calculation of Glass Constants in Form of Individual Functions of the Oxides in Given Fundamental Glasses," *Sprechsaal*, 59, 249, 265, 282, 297 (1926); *Ceram. Abs.*, **6** [4] 140 (1927); "Contributions to Theory of Calculation of Glass Constants by Method of G. Gehlhoff," *Sprechsaal-Beihefte*, Nos. 1 and 2 (1927); for review, see *Jour. Soc. Glass Tech.*, **12** [45] 32–118 (1928); p. 85.

maintains a constant value. Linear additivity is valid when such isolines are straight.

(ii) *Regular Variation (First Kind):* If composition is expressed in relative numbers as $aA \cdot \underline{b}B \cdot wC$ for a certain series of glasses, $\underline{b}$ is constant and w is the only variable. A straight line resulting from a plot of any property against w indicates that the linear-addition rule applies. The substitution of other values for $\underline{b}$ results in a graphic series.

For a composition expressed in percentages as $xA \cdot (\underline{b}/a)x \cdot zC$ (the total is 100) for a definite value of $\underline{b}$, composition may be expressed in a single variable, z, and any property may be graphed as a function of the percentage of component, C. A straight line resulting again indicates the validity of linear addition.

(iii) *Regular Variation (Second Kind):* For this type, representative number expressions are proportional to percentages, and, for a particular value of $\underline{a}$, there is but one variable in either case. Graphs of properties against this variable will give indications as to the correctness in assuming linear additivity.

Zschimmer[55] recommends third-dimensional plots of properties against composition.

(4) Tetra- and Poly-Component Systems

Although compositions of four-component systems can be expressed with the aid of a regular tetrahedron and the foregoing discussions for ternary systems may be applied, the situation is complicated. For poly-component systems, regular variations of the first kind may be used and similar but more involved results are obtained.

For practical or commercial purposes, the method used by Gehlhoff and Thomas (pp. 317 and 318) was highly advocated by Zschimmer.[56]

[55] E. Zschimmer, "Physical Properties of Glasses as a Function of Chemical Composition," *Z. Elektrochem.*, 11 [38] 629–38 (1905).

[56] See footnote references 54(*a*) and 55.

Department of Chemistry
University of Pittsburgh
Pittsburgh, Pennsylvania

(Part II, the conclusion of this paper, will appear in the December issue of *The Journal*.)

REACTION BETWEEN METALS AND MOLTEN GLASS*

By A. E. Badger and B. Bard

Abstract

A series of melts of soda-lime-silica glass cullet in contact with various chemical elements was made to determine by observation the extent of the reaction between metal and glass. The heat treatment consisted of a period of two hours at about 1250°C. An atmosphere of hydrogen gas was used to protect the element from oxidation during the the test period. Various colors were produced by Cu, Ag, Au, Se, C, S, and Zr. Black fogs resulted from melts containing Ba, Cr, or V; gray or black fogs with reddish zones resulted from Mg, Ca, Ti, Mn, Si, and Al. A faint blue with large reddish zones was produced by Co. Only slight attack was shown by Fe, Ni, Zn, Cd, Bi, Sn, Pb, Mo, and W.

I. Introduction

Various observations on reactions between metals and molten glass have been made in practical glass manufacture. The formation of seed when commercial iron is accidentally introduced in glass furnaces, the colors produced by electrodes in contact with molten glass, as well as the colored glasses formed by colloidal gold, copper, and selenium are visible evidences of such reactions.

The tendency of chemical elements to form colloidal fogs in fused salts, that is, pyrosols, is exhibited by melts of many elements in their chlorides (Zn in $ZnCl_2$, Na in NaCl, etc.) and also in many industrial operations, such as the formation of an aluminum fog in the electrolytic production of that metal.

A series of experiments was made in order to observe the formation of colloidal fogs when various metallic elements (and a few nonmetals) were heated in contact with a molten soda-lime-silica glass. The elements that were used consisted of those which are available commercially at moderate cost, namely, copper, silver, gold, magnesium, calcium, zinc, cadmium, barium, aluminum, carbon, zirconium, silicon, tin, lead, vanadium, antimony, bismuth, sulfur, chromium, selenium, molybdenum, tungsten, manganese, iron, cobalt, and nickel. The metals were of c.p. grade and were in the form of wire, powder, pellets, or granules.

II. Method of Experiment

A small amount of the chemical element, about $^1/_2$ cc. in volume, was placed in the bottom of a porcelain crucible (25-cc. capacity) which was filled with crushed soda-lime-silica glass, a commercial bottle glass composition. The crucible was then placed near the closed end of a gas-tight porcelain tube which was inserted in a platinum-wound electric furnace (Fig. 1). Hydrogen gas was circulated in the tube to

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prevent oxidation of the element during the heat treatment, which consisted of a period of two hours at 1250°C. At the end of the heat treatment, the crucible was quickly cooled and broken open to observe the condition of the glass. In the case of the test with graphite, the element had floated to the glass surface. In the other tests, the elements were in the bottom of the crucibles except as noted in Table I.

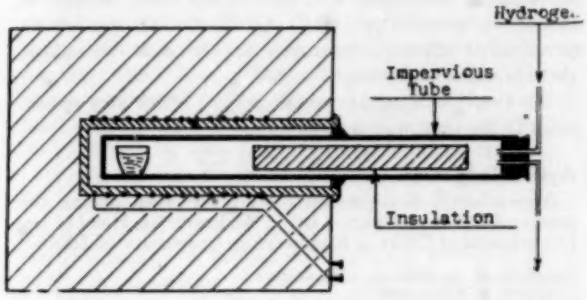

FIG. 1.—Platinum-wound electric furnace containing gas-tight tube through which hydrogen was passed to protect contents of crucible from oxidation.

III. Results and Discussion

Table I provides a summary of the appearance of the glasses after being heated in contact with various chemical elements for a period of two hours at 1250°C. The melting and boiling points of these elements are listed also.[1]

The results of Table I may be summarized approximately in the following groups: (*a*) copper, silver, gold, and selenium produced glasses with the straw-to-reddish tints which these elements usually impart to glasses; (*b*) carbon, sulfur, and zirconium formed glasses with streaks of amber; (*c*) barium and chromium caused the formation of dense black glasses, and vanadium produced a similar result, except for an amber color near the top; (*d*) magnesium, calcium, titanium, manganese, and aluminum formed gray or black fogs with reddish areas near the top or sides of the crucible; (*e*) silicon produced a reddish-gray fog; (*f*) iron and nickel produced greenish-yellow glasses; (*g*) cobalt caused a very faint blue with distinct parts of the melt being reddish; and (*h*) fairly colorless glasses resulted from melts containing zinc, cadmium, bismuth, tin, lead, antimony, molybdenum, or tungsten.

Whether the black fogs produced in (*c*) and (*d*) resulted from the formation of colloidal fogs of these elements or whether the original elements replaced silicon in the glass with the formation of colloidal silicon has not been determined. As silicon caused a reddish fog, the reddish areas of the glasses named in (*d*) may be due to colloidal silicon. Cobalt, however, formed reddish glasses, and it seems probable that many of the elements existed in the colloidal state which formed this color.

[1] International Critical Tables, **1**, 102–103 (1926). McGraw-Hill Book Co., New York.

The quite colorless glasses, resulting from melts containing zinc or cadmium, might have been caused by the loss of these metals by volatilization during the test period. Similar glasses from tests with molybdenum or tungsten probably were due to the low vapor pressures of these metals and the consequent small tendency to form colloidal fogs.

TABLE I

SUMMARY OF RESULTS AFTER HEATING CHEMICAL ELEMENTS IN CONTACT WITH MOLTEN SODA-LIME-SILICA GLASS FOR TWO HOURS AT 1250°C.

Chemical element	Melting point (°C.)	Boiling point (°C.)	Appearance of melts
Copper	1083	2300	Glass near metal colored red; remainder clear
Silver	960	1950	Glass clear except for scattered brown streaks
Gold	1063	2600	Glass uniform straw color
Magnesium	651	1110	Black fog throughout glass; faint red on top
Calcium	810	1170	Same as magnesium
Zinc	419	907	Clear glass except for black areas on surface
Cadmium	321	767	Clear glass with faint yellow tint
Barium	850	1140	Dense black fog throughout glass
Aluminum	660	1800	Gray fog except for reddish-brown surface parts
Carbon	3500	4200	Different parts of melt clear to amber
Silicon	1420	2600	Colorless glass with reddish part near surface; many bubbles
Titanium	1800	arc	Black fog throughout melt except for red on surface and near sides of crucibles
Zirconium	1700	Ca. 2900	Bubbly glass with streaks of amber
Tin	232	2260	Clear glass with greenish tint
Lead	327	1620	Clear glass
Vanadium	1710	3000	Black fog except for amber surface and edges near crucible
Antimony	630	1380	Similar to tin
Bismuth	271	1450	Similar to lead
Sulfur	113	445	Clear glass with amber streaks near surface
Chromium	1615	2200	Black fog
Selenium	220	688	Clear glass with brownish-red color
Molybdenum	2620	3700	Clear glass with faint yellow color
Tungsten	3670	5900	Clear glass
Manganese	1260	1900	Similar to titanium
Iron	1520	2450	Greenish-yellow glass
Cobalt	1480	2900	Clear glass, most of which was a faint blue; distinct parts red
Nickel	1452	2900	Greenish-yellow glass; black fog near metal

EDITORIAL DISCUSSION

Most of the effects produced may be explained by the interaction of the oxygen from the batch constituents with the metal added. The typical color produced by iron is a series starting with a blue when the iron oxide is reduced and green to orange, when the iron is strongly oxidized. The fact that iron gave a "greenish-yellow"

glass would indicate that considerable oxygen had been taken from the batch.

Another matter of importance is the possible presence of traces of sulfur in the glass. Unless c.p. materials are used and melted without flame it is almost impossible to get a glass strictly sulfur-free. Traces of sulfur in the glass in the presence of a reduced metal and a hydrogen atmosphere might account for some of the yellow color. It is to be regretted that no blanks were run.

The atmosphere should be merely inert rather than reducing to avoid possible reaction of hydrogen (reduction) with common elements in the glass.

The reaction of metals like chromium, which could remove oxygen from metallic (or silicon) oxides, should also be taken into consideration.

Reply by A. E. Badger

The tests were made as a survey to determine the elements that might produce only slight contamination of molten glass. The possible reactions between the added element and the dissolved gases in the glass (notably water) were considered. Such interaction seemed to exist in some cases, but observations were indefinite as the melts were not visible during the tests.

Blank tests were made, of course, and the glass did not show any pronounced change in appearance.

An inert atmosphere (as nitrogen) was not used because it was impossible under the test conditions to prevent the presence of small amounts of oxygen in the interior of the refractory tube. The use of a hydrogen atmosphere prevented the uncertainty that would be caused by traces of oxygen. As blank tests showed no pronounced effect of hydrogen on the soda-lime glass, there is slight objection to its use.

The reaction of metals (as chromium) which may reduce silica in the glass was mentioned in the text.

Acknowledgment

Appreciation is expressed for advice given during the course of the investigation by C. W. Parmelee, Head of the Department of Ceramic Engineering, University of Illinois.

Department of Ceramic Engineering
University of Illinois
Urbana, Illinois

DISCUSSION ON "THERMAL ENDURANCE OF GLASS CONTAINERS" BY F. W. PRESTON*

By J. B. Murgatroyd

In the issue of the *Journal of The American Ceramic Society* for April, 1940, F. W. Preston refers to some of my work on the thermal endurance of containers. I was very much interested in this mathematical study of the stresses produced by a temperature gradient near the joint of the base and side of a bottle as Dr. E. J. Gooding and I for some years have sought a formula to express the thermal endurance of bottles.

Dr. Preston mentions in his paper that, although I reported that the maximum stress under thermal shock occurs in the side wall near the base, I did not attempt to explain the matter. This is not actually the case as will be seen on referring to my paper which appeared in the *Journal of the Society of Glass Technology*, Vol. 16, p. 5, in 1932. In this paper, the phenomenon was explained as being due to the concentration of stress at the base side join owing to temperature differentials across a section of glass in the base and the side. Dr. Preston has expressed the same thing mathematically and his explanation is therefore an improvement on mine. I should, however, like to draw attention to the fact that his statement that my empirical results were not explained is not the case.

As a matter of interest, I have applied Preston's new formula to results which we have obtained in our Laboratory. We have worked on similar formulas without success but have not used the one he proposes. Because the measurements are available, I shall give them for a series of bottles covering a range of diameters from 1.2 to 5.2 inches. Whenever we have attempted to obtain a formula, we have used this fairly wide range because, in our experience, many formulas will fit a comparatively small range of bottles, but they break down when the following range is considered (Table I).

Table I

Description	R (in.)	l (in.)	r (in.)	h (in.)	J	$J\bar{\theta}$	$\bar{\theta}$	$\bar{\theta}\sqrt{D}$
100-oz. jar	2.6	0.14	0.44	0.27	1.5	165	110	252
9-oz. jar	1.2	0.10	0.16	0.17	1.8	227	126	195
Pint beer	1.5	0.23	0.22	0.32	2.1	246	117	207
1/2-oz. ink	0.7	0.13	0.10	0.16	2.3	402	175	193
14-oz. jar	1.8	0.13	0.19	0.23	2.2	264	120	224
14-oz. jar (overweights)	1.8	0.18	0.19	0.25	2.2	257	117	216
26-oz. whiskey	1.5	0.20	0.22	0.29	2.0	250	125	219

We defined the average breaking temperature as the temperature differential required to break 50% of the bottles and we used the Preston machine. The results represent the average of many tests on each type. The bottles were carefully handled from the lehr so that bruising should not affect the results. In the case of the 1/2-oz. ink bottle, the necessary temperature differential was obtained by a different test, simulating the Preston machine procedure, and the average breaking temperature was obtained by extrapolation so that the θ value is probably accurate only to ±15°F.

The notation used in Table I is that of Preston's paper, and in the last column is given the value of $\bar{\theta}\sqrt{D}$. In my paper, which appeared in *Glass*, Vol. 8, p. 272, 1931, I mentioned that the value of the average breaking temperature multiplied by the square root of the diameter of a bottle was approximately constant, and it will be seen

* Mr. Murgatroyd wrote this discussion on May 2, 1940, from the Rockware Glass Syndicate, Ltd., Middlesex, England.

that, over the fairly wide range given in Table I, the variation for this value is within ±14% of the mean, whereas the $J\theta$ value varies ±48% around the mean. This would indicate that the $J\theta$ value is not a constant over a fairly wide range of bottles.

I should like to add that I have no explanation to offer as to why $\theta\sqrt{D}$ is approximately constant except that whenever a series of results fails to correlate in any way, the use of square roots will often show an apparent correlation. In other words, I suspect that there is no physical meaning to be attached to the figure although it may be connected with the fact that, as the diameter of a bottle increases, the chance of a flaw occurring in the right orientation and in the right place also increases. It appears, therefore, that when we apply our test set of results to the new Preston formula we are unable to substantiate it.

We have also found that formulas of similar types are not confirmed in practice, and we believe that this is due to the fact that the premise of a uniform temperature gradient cannot be applied directly to the results of shock tests. An indication of this will be found in Mallinson's "Study of a Uniform Plate Chilled on One Surface," published in Gould and Hampton's paper (*Jour. Soc. Glass Tech.*, **14**, 188 (1930)). Formulas which incorporate the premise of a straight-line temperature gradient are probably more applicable to the results of tests in which bottles are filled with hot water while standing in cold water. In such tests, the temperature gradient which causes failure is built up by heating the inside face, and the breaking condition is reached when conditions more nearly approaching a straight-line temperature gradient have been obtained.

Finally I should like to mention a fact that we have observed in chill tests using the Preston machine. If the thickness of the side wall near the base is noticeably less than the thickness of the wall approximately halfway up the bottle, the type of fracture produced is basal, that is, the fracture runs round the base-side join. If, however, the thickness of the wall near the base exceeds the wall thickness halfway up the bottle, the fracture runs vertically down the bottle and into the base without running round the base-side join. This indicates failure under different types of stress at right angles to one another in the two cases, but again we have been unable to find any relation between the types of fracture and the thermal endurance. I reported this to the London Section of the Society of Glass Technology in March, 1940.

I await Dr. Preston's usual vigorous treatment of these matters with interest.

Reply by F. W. Preston†

I have reread Mr. Murgatroyd's article in the *Journal of the Society of Glass Technology*, 1932, and feel that, in my own article, I might have been more courteous and analyzed his work more fully. Mr. Murgatroyd is one of the few people who, to my knowledge, has grasped the essentials of the situation arising in thermal shock, and I have little fault to find either with his original presentation or his present comments. It happens that, historically, my own paper had no connection with his, and it was written when I was stationed far away from my laboratory and without access to the literature. Trouble had arisen, which was traced to bruising in that region of the bottle which I have called the Murgatroyd belt, and the question arose as to what strength might reasonably be expected of that region. The manuscript which I then prepared came to be in so much demand that, after a few years, it seemed best to publish it, and I might with advantage have then reviewed the literature.

If I understand Mr. Murgatroyd's Fig. 3 correctly, it illustrates much that I have tried to explain, though the figure itself is misleading. The base of a bottle tends to crown or camber as shown, but the sides do not unless they are split. The corollary to this is that the base tends to be free of stress in spite of the temperature gradient, whereas the side walls are stressed by the inability of a cylinder to curl or distort in such a fashion that each element of glass has a length appropriate to its temperature. Thus, under a static (linear) temperature gradient, an infinite disk is free of stress, though cambered; whereas an infinitely long cylinder is stressed though it is still cylindrical.

The problem then is what happens at the junction of the two when they are combined to form a container or bottle. Mr. Murgatroyd says (*loc. cit.*, p. 13), "The glass at the angle between base and side endures the maximum bending moment, and hence failure begins there." This is true and is the core of the whole matter, though we might add a caution that bending moments are not the only way of producing stresses in bottles. But the fact that it is so seems to me a tribute to Mr. Murgatroyd's intuition rather than to his exposition; the figure itself proves nothing, and the text, showing clearly, in this and other points, the exactness of his conclusions, does not indicate, to my slower-moving mind, any method of reaching those conclusions.

I may add that Mr. Murgatroyd's original statement seems to me far clearer than this one in his present comment, "The phenomenon was explained as being due to the concentration of stress at the base side-wall join due to the temperature differential across a section of the glass in the base and the side." The mere presence of temperature differentials does not necessarily involve any stress at all, still less a concentration of stress; and Fig. 3, if it is related to a two-dimensional case instead of a three-dimensional, would not involve either stress or concentration of stress.

The experimental results, when expressed numerically, are unsatisfactory, whether they confirm or dispute the theory. There are too many other things that have to be taken care of. The practical solutions of the problem, discussed in Dr. Ghering's paper, are perhaps our chief consolation.

Box 847
Butler, Pennsylvania

† Received June 6, 1940.

APPARATUS AND METHOD FOR THE DETERMINATION OF POROSITY IN REFRACTORY MATERIALS*

By Gilbert E. Seil, Bradford S. Tucker, and H. A. Heiligman†

Abstract

The construction and operation of a mercury volumeter suitable for determining the volume of a composite sample of refractory grains is described. Porosity determinations by the method described are accurate within ±0.15%. Convenient volume-density-porosity conversion charts are included.

I. Introduction

The methods generally used for the determination of the porosity of refractory materials do not completely fulfill the requirements of the refractories industry. The methods in general use depend on the saturation of a weighed sample of the refractory material with a liquid and also on the calculation of porosity from the dry weight of the sample, the saturated weight of the sample, and the weight of the sample suspended in the liquid. Unavoidable errors are introduced in obtaining the weights because it is difficult to remove the liquid from the surface of the sample in exactly the right degree. If insufficient liquid is removed, a high saturated weight is obtained; if, in removing the surplus liquid from the surface of the sample, some of the liquid is removed from the pores of the saturated sample, the saturated weight is too low. Experiments with different materials, such as cotton, wool, and chamois (dry, moist, and saturated) for drying the samples, have not eliminated the difficulty. None of the methods so far suggested, depending on the saturation of the sample, yields results within a reasonable limit of error. Careful work on the same sample often gives a negative quantity for the calculated volume of the sealed pores. This in itself is indicative of the inaccuracies in methods which depend on saturating the pores in the sample.

Another method for determining porosity depends on the determination of the volume of the sample by the displacement of mercury, the expansion of gas in the pores to determine the partial pressure of the gas in a known volume, and the calculation of the volume of the pores from the partial pressure obtained. This method gives good results provided the humidity is absolutely controlled and the pores are not sealed.

II. Apparatus

(1) Pycnometer

The true specific gravity of the sample is determined by the usual method, using a pycnometer.

(2) Volumeter

The apparatus used for determining the apparent volume of the sample is shown in Figs. 1 and 2.

A ring stand with two 1/2-inch cold-rolled round rods, set 6 inches center to center on a base bolted to the table is used to support the apparatus. One rod supports two burettes, *A* and *C*, having large-bore stopcocks, *H* and *G*, respectively. Care must be taken that there is no constriction in the burette tips. The second rod is equipped with a ring stand supporting a 125-cc. separatory funnel, *B*, which serves as the sample-retaining chamber, and a portion of the ring has been removed to allow the easy removal and replacement of the sample chamber. As no rubber tubing has been found which does not stretch to some extent with variations in pressure owing to the mercury level, flexibility was obtained by the use of glass tubing connected end to end with pressure rubber tubing. An ell is used to connect the sample chamber to tube 1, which in turn is connected with tube 2 (see Fig. 1).

Tubes 1 and 2 are 24 inches long with 1-inch ells bent parallel and on the same side of each tube. Ells 3 and 5 and tee 4 connect burettes *A* and *C* to tube 2. A 125-cc. mercury reservoir, *D*, is connected to the burette, *C*, with a rubber tubing stopper.

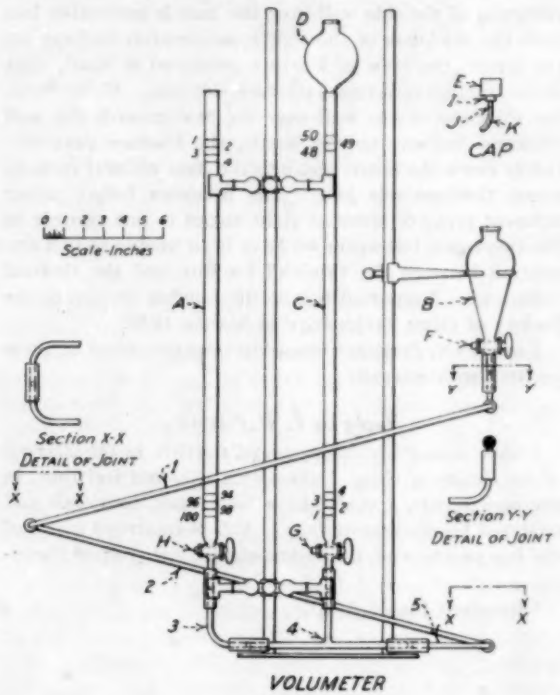

FIG. 1.

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 10, 1940 (Refractories Division). Received April 4, 1940.

† G. E. Seil, Technical Director; B. S. Tucker, Ceramic Engineer; and H. A. Heiligman, Assistant Technical Director, E. J. Lavino and Company, Norristown, Pa.

The sample chamber is equipped with a heavy steel cap, *E* (Fig. 2). *J* is a small round piece of screen wire which prevents the sample from floating out of the sample chamber, *D*. The shoulder, *I*, should fit snugly into the mouth of the separatory funnel, *B*. The diameter of the stem connecting *I* to the screen, *J*, should be $^1/_2$ to $^1/_4$ inch less than the diameter of the shoulder. *K* is an agitator to eliminate any air clinging to the sample.

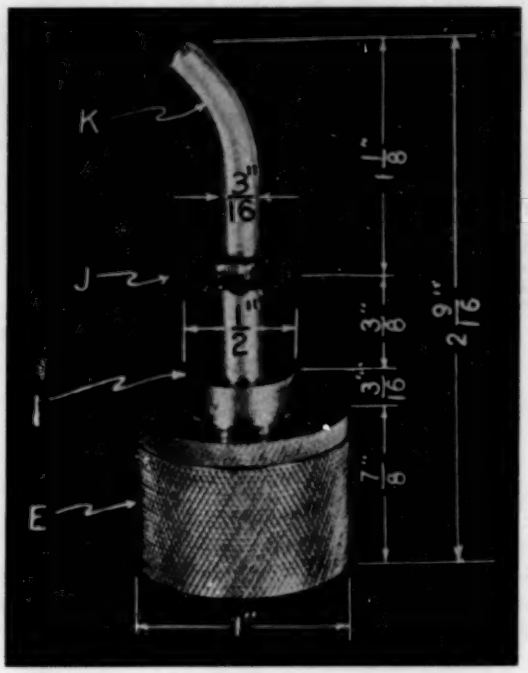

FIG. 2.

III. Procedure

The method depends on the fact that mercury neither wets nor enters the pores of refractory grains. The displacement of mercury by the grains therefore is a direct measure of the apparent volume of the grains.

(1) Pycnometer

The absolute volume of the grains is determined by dividing the number which represents the weight in grams of the grains by the number which represents the true specific gravity as determined by the pycnometer method. Inasmuch as most of the grains react to some extent with water, either because of soluble salts or because of hydration, it is necessary to use some other liquid in the pycnometer. Toluene is used by the writers.

The pycnometer is calibrated with water at 25°C., and the specific gravity of the toluene at 25°C. is determined. Five grams of a prepared grain sample (−325-mesh) are dried and placed in the pycnometer, to which there has been added a small quantity of toluene. The pycnometer is placed in a beaker which contains a small layer of mercury and is heated until the toluene boils slightly. The equipment is cooled, filled with toluene, brought to temperature, and weighed. The true gravity is determined by the usual calculations.

(2) Sample

The apparent volume is obtained on a 100-gram portion of a representative sample of grain or crushed brick which passes a screen with $^3/_8$-in. square openings and remains on a screen with openings $^1/_4$ inch square. Care must be taken to avoid small pieces in the sample as the mercury will not displace air in very small voids between the grains.

(3) Operation of Volumeter

To calibrate the system, clean, dry mercury is added to burette *A*, stopcock *H* is opened, and stopcock *G* is closed until the system is full of mercury and all the air bubbles have been removed. The cap, *E*, is placed in the sample chamber, *B*.

The support of the sample chamber, *B*, is lowered and mercury is allowed to enter until the top of the meniscus touches the projection, *I*, of the heavy steel cap, *E*. Stopcock *F* on the sample chamber is then closed. It is preferable to have reverse readings on burette *C*. The mercury is allowed to enter *C* from the burette, *A*, by opening stopcock *G* until the top of the meniscus is at the lowest mark on the burette. Stopcock *H* is now closed and kept closed until the determination is completed. Sample chamber *B* is raised in its supporting ring until the center of *B* and the center of the reservoir, *D*, are approximately at the same level; stopcocks *G* and *F* are then opened to allow the mercury to flow into reservoir *D* and to drain the sample chamber sufficiently to provide room for the sample. Stopcock *F* is now closed; sample chamber *B* is lowered in its support until level with the 25-cc. mark on burette *C*; the cap, *E*, is removed from sample chamber *B*; 100 grams of the sample are added; the cap is replaced; and the mercury is allowed to re-enter the sample chamber by opening cock *F* until the meniscus touches projection *I* of the heavy steel cap, *E*. Cap *E* is rotated until the air around the grains is eliminated. The burette, *C*, is then read, and the amount of mercury displaced is determined by subtracting this reading from the original reading. If a burette with reversed readings is used, the amount of mercury displaced by the sample is read directly. The operation is repeated five to ten times to check the readings.

The mercury is drained from sample chamber *B* until it is within an inch of stopcock *F*, which is then closed. The sample and remaining mercury are removed. This mercury is easily cleaned by passing it through a tube filled with calcium chloride. The sample chamber should be wiped clean after each determination.

(4) Calculations

In this method, the figures of only three determinations are needed to calculate the porosity of a sample, namely, (*a*) true specific gravity, (*b*) weight of sample, and (*c*) volume of sample.

The following formula is used:

$$\text{Porosity (\%)} = \frac{V_2 - V_1}{V_2} \times 100,$$

wherein V_1 = weight (grams) of sample divided by its true specific gravity.
V_2 = apparent volume of sample (cc.).

IV. Advantages

The advantages of the method described lie in the fact that it is applicable to the determination of porosity on a composite representative sample either of refractory grain or of a crushed refractory body rather than on a single portion of a refractory body as is the case with the saturation methods. In determining the porosity of brick, a representative sample from any number of brick may be prepared.

It is also possible to take samples from any portion of a brick and determine the porosity in that portion. Any variation in porosity throughout the brick may thus be established. This is illustrated in Table II.

The porosities of three samples of refractory grains were determined by three methods, using the same sample for all three methods. The results are given in Table I.

The porosity obtained by using the water-saturation method shows variations from 1 to 7 units of porosity. The values obtained by using the kerosene-saturation method varied from 3 to 5 units. The highest variation in the mercury displacement method was 0.25 unit.

The conversion charts (Figs. 3 and 4) are convenient to use, and if they are manipulated carefully, they are accurate to 0.25 unit of porosity.

V. Manipulation of Graph

(*1*) *Known:* True specific gravity. *Find:* True volume of 100 grams.

TABLE I

POROSITY OF REFRACTORY GRAINS

	Sample A (method)			Sample B (method)			Sample C (method)		
Determination No.	Water	Kerosene	Mercury	Water	Kerosene Porosity (%)	Mercury	Water	Kerosene	Mercury
1	8.58	11.0	9.88	30.93	30.0	29.72	17.73	23.0	23.49
2	7.84	10.0	9.88	28.93	30.0	29.72	22.78	23.0	23.49
3	7.39	10.0	10.03	29.19	30.0	29.90	25.26	23.0	23.59
4		8.0	10.03		30.0	29.90		21.0	23.59
5		11.0	10.03		34.0	29.90		25.0	23.49
6		8.0	10.03		35.0	29.90		31.0	23.39
Avg.	7.93	9.6	9.98	29.68	33.0	29.84	21.92	24.3	23.50
Range of variations	1.19	3.0	0.15	2.0	5.0	0.18	7.53	8.0	0.20

TABLE II

POROSITY (%) AND BULK DENSITY OF VARIOUS SECTIONS OF STANDARD BRICK

Accuracy of porosity, ±0.15; accuracy of weight/100 cu. in., ±0.015 lb.; true specific gravity, 3.826.

		Brick No. (9 by 4½ by 3 inches in size)							
		1	2	3	4	5	6	Avg.	Max. variation
Front end	Porosity (%)	24.84	25.42	25.82	25.95	24.43	27.39	25.64	2.96
	Weight/100 cu. in.	10.39	10.31	10.25	10.23	10.44	10.04	10.28	0.40
Back end	Porosity (%)	23.57	23.52	24.17	23.90	23.07	25.61	23.97	2.54
	Weight/100 cu. in.	10.56	10.57	10.48	10.52	10.63	10.28	10.51	0.35
Top or brand face	Porosity (%)	23.95	23.43	24.67	23.97	24.21	26.37	24.43	2.94
	Weight/100 cu. in.	10.51	10.58	10.41	10.51	10.47	10.18	10.44	0.40
Bottom	Porosity (%)	23.75	23.92	24.28	24.06	23.79	25.93	24.29	2.18
	Weight/100 cu. in.	10.54	10.51	10.47	10.50	10.53	10.24	10.47	0.30
Core or actual center	Porosity (%)	23.79	22.89	24.45	23.34	24.23	25.31	24.01	2.42
	Weight/100 cu. in.	10.53	10.66	10.44	10.59	10.47	10.32	10.50	0.34
Avg.	Porosity (%)	23.98	23.84	24.68	24.24	23.95	26.12	24.47	2.61
	Weight/100 cu. in.	10.51	10.53	10.41	10.47	10.51	10.21	10.44	0.36
Max. variation	Porosity (%)	1.27	2.53	1.65	2.61	1.36	2.08	1.92	
	Weight/100 cu. in.	0.17	0.35	0.23	0.36	0.19	0.28	0.26	

		Brick No. (9 by 4½ by 2½ inches in size)							
		1	2	3	4	5	6	Avg.	Max. variation
Front end	Porosity (%)	27.37	30.48	27.29	32.03	24.88	24.18	27.70	7.85
	Weight/100 cu. in.	10.12	9.69	10.13	9.47	10.47	10.56	10.07	1.09
Back end	Porosity (%)	25.06	28.03	24.99	30.11	22.99	23.06	25.71	7.12
	Weight/100 cu. in.	10.44	10.03	10.45	9.74	10.73	10.72	10.35	0.99
Top or brand face	Porosity (%)	26.17	28.57	25.89	23.74	25.89	23.28	25.59	5.29
	Weight/100 cu. in.	10.29	9.95	10.33	10.63	10.33	10.69	10.37	0.74
Bottom	Porosity (%)	26.17	28.01	25.68	23.65	23.15	26.13	25.47	4.86
	Weight/100 cu. in.	10.29	10.03	10.35	10.64	10.71	10.29	10.39	0.68
Core or actual center	Porosity (%)	25.96	28.37	26.08	30.30	25.79	22.92	26.57	7.38
	Weight/100 cu. in.	10.32	9.98	10.30	9.71	10.34	10.70	10.23	0.99
Avg.	Porosity (%)	26.15	28.69	25.99	27.97	24.54	23.91	26.21	6.50
	Weight/100 cu. in.	10.29	9.94	10.31	10.04	10.52	10.59	10.28	0.90
Max. variation	Porosity (%)	2.31	2.47	2.30	8.38	2.90	3.21	3.59	
	Weight/100 cu. in.	0.32	0.34	0.32	1.17	0.40	0.43	0.50	

Locate true specific gravity on left ordinate scale; follow this value to its intersection with the volume-density curve; read the true volume below this intersection on the abscissa scale.

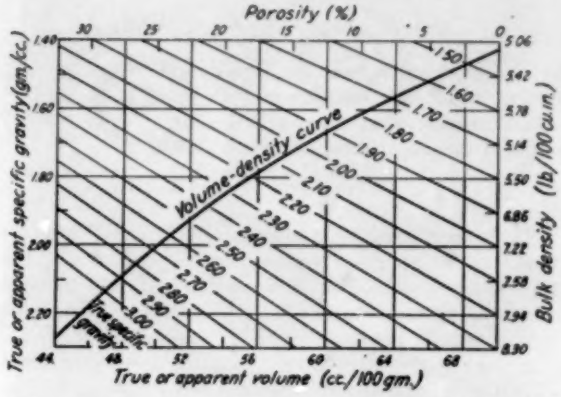

FIG. 3.—Conversion chart for volume, density, and porosity.

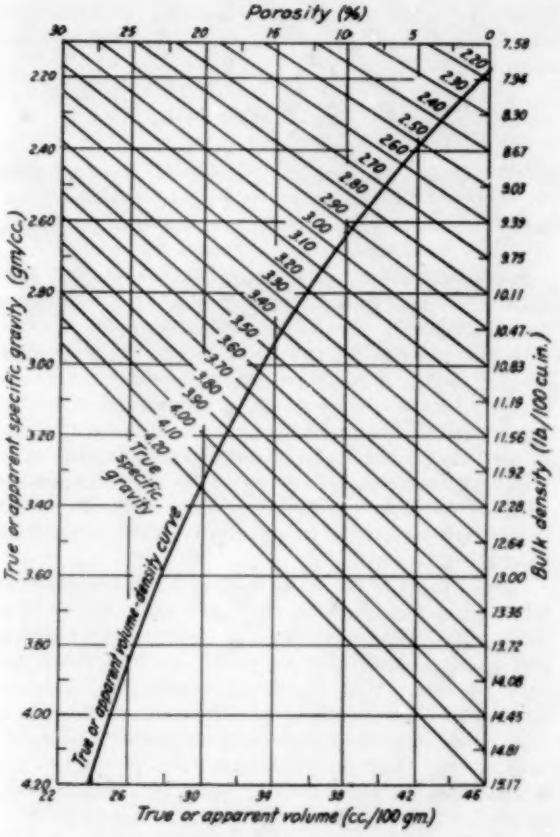
Porosity (%)
True or apparent specific gravity (gm./cc.)
True specific gravity
True or apparent volume density curve
Bulk density (lb./100 cu.in.)
True or apparent volume (cc./100 gm.)

FIG. 4.—Conversion chart for volume, density, and porosity.

(2) *Known:* Apparent volume. *Find:* Apparent specific gravity and bulk density.

Locate the apparent volume on the abscissa scale; follow this value up to its intersection with the volume-density curve; from this point, read horizontally on left and right ordinate scales for apparent specific gravity and bulk density, respectively.

(3) *Known:* True specific gravity and apparent volume of 100 grams. *Find:* Porosity (%).

Locate apparent volume on lower abscissa scale; follow this value to the volume-density curve; follow this point horizontally left or right to the diagonal true specific gravity line which represents the sample; read the percentage of porosity above this intersection on the abscissa scale.

(4) *Known:* Apparent specific gravity and true specific gravity. *Find:* Porosity (%).

Locate apparent specific gravity on the left ordinate scale; follow this value to its intersection with the diagonal true specific gravity line; read the percentage of porosity above the intersection on the abscissa scale.

(5) *Known:* Bulk density and true specific gravity. *Find:* Porosity (%).

Locate bulk density on the right ordinate scale; follow this value to its intersection with the diagonal true specific gravity line; read the percentage of porosity above this intersection on the abscissa scale.

VI. Conclusions

(1) The mercury displacement method of determining the porosity of refractory grains is accurate within ±0.25 unit of porosity; (2) it allows a composite sample to be used for the determination; (3) it eliminates the inaccuracies inherent in methods wherein free liquid is removed from the surface of the sample; (4) it eliminates the error due to closed pores in the sample; (5) it is adaptable to any type of ceramic material; and (6) it does not determine the size or the placement of the pores nor does it have any bearing on the distribution of the pores although it does differentiate between holes in the refractory and in the pores; an exact definition, however, of a hole and a pore is not given.

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E. J. LAVINO AND COMPANY
NORRISTOWN, PENNSYLVANIA

USE OF CAST ALUMINA REFRACTORIES IN THE GLASS INDUSTRY*

By H. N. Baumann, Jr., and A. A. Turner†

Abstract

The development of cast alumina refractories is briefly described, and the physical and chemical properties of three types of high-alumina, fusion-cast refractories that have proved commercially successful are given. Such properties as microstructure and glass-refractory interface reactions are discussed, and the use of these refractories with several different types of glass is described.

I. Introduction

The production of refractories with improved resistance to corrosion and erosion has long been one of the major problems of the glass industry. To obtain even passable tank life with corrosive fluoride and borosilicate glasses, glass compositions sometimes have been altered to favor the refractories. Operating temperatures and production rates therefore have been limited frequently by the type of refractories used.

In undertaking the development of refractories with marked superior corrosion resistance, no preconceived ideas of composition and structure or of method of fabrication were at first accepted. The destructive effects of the more corrosive glasses were studied as well as the reactions and rates of corrosion of soda-lime glasses, metallurgical slags, enamels, frits, and chemical fusions. This study is still in progress, and a number of refractories of different composition and structure are in the development stage. Three types of fusion-cast alumina, however, have proved to be commercially useful, and this paper is chiefly concerned with their physical and chemical properties.

II. Preliminary Studies

This study was begun by investigating the mechanism of attack and failure of the commonly used refractories. A representative number of specimens of new and used refractory materials was obtained, and these specimens were studied from the standpoint of their physical and petrographic properties. Particularly interesting were the interfaces of the used refractories. A typical interface between a soda-lime glass and a clay refractory is shown in Fig. 1 (*a*). The need of actually seeing some of these reactions take place was recognized, which led to the development of the thermal microscope. Typical reactions may be observed with this microscope, both directly and by cinephotomicrography, so that they may be studied leisurely and, in some cases, at an accelerated rate.‡

These preliminary studies served to indicate (1) that, as far as glass composition is concerned, the silica content should be eliminated or radically reduced and (2) that alumina is relatively stable and extensive studies should be made on high-alumina compositions. The studies also showed that, relating to the structure of corrosion- and erosion-resistant refractories, the continuity of the pore structure and the less refractory bonds should be eliminated, and a thorough interlocking or embedding of the larger grog or crystalline particles should be secured. The development of fused-cast alumina refractories seemed to fulfill these requirements.

III. Small-Scale Tests

Although the possibility of designing a laboratory simulative service test was considered, it was finally decided that all corrosion tests on glass should be conducted at a glass plant under conditions approaching, as closely as possible, those of commercial work.

Small test pieces accordingly were cast and partially submerged in a day tank or in a small continuous tank to evaluate the nature and severity of reaction with borosilicate, fluoride, and highly alkaline soda-lime glasses. A wide range of compositions was covered by these tests which in general indicated the superiority of compositions high in alumina and also showed that fusions which have a predominantly crystalline structure with little or no interstitial glass are superior to fusions in which glass predominates. A fusion highly glassy in its structure is no more resistant than the glass itself.

On the basis of these preliminary tests, many of the mixes were eliminated from further consideration. The outstanding compositions were frequently re-tested, and each constituent was varied up and down the scale to select that composition with the optimum amount of each constituent. Throughout all of these tests it was important that the glass quality be entirely satisfactory. Compositions suspected of causing difficulty from the standpoint of seeds, for example, were immediately eliminated from further consideration. A number of the compositions selected have now been patented, and additional patents are pending.

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† H. N. Baumann, Jr., Research Department, Carborundum Company, Niagara Falls, N. Y.; A. A. Turner, Refractories Division, Carborundum Company, Perth Amboy, N. J.

‡ Some of this petrographic and thermal microscopic work was described by Dr. Tone before the Electrochemical Society at the time he received the Acheson medal (F. J. Tone, "Super-Refractories," *Trans. Electrochem. Soc.*, **68**, 22–26 (1935)). The film was also shown to The American Ceramic Society at the Columbus Meeting in 1936 (motion picture presented by Research Laboratory, the Carborundum Co., R. C. Benner, Director; note on "Super-Refractories Through the Microscope," *Bull. Amer. Ceram. Soc.*, **15** [7] 255 (1936)).

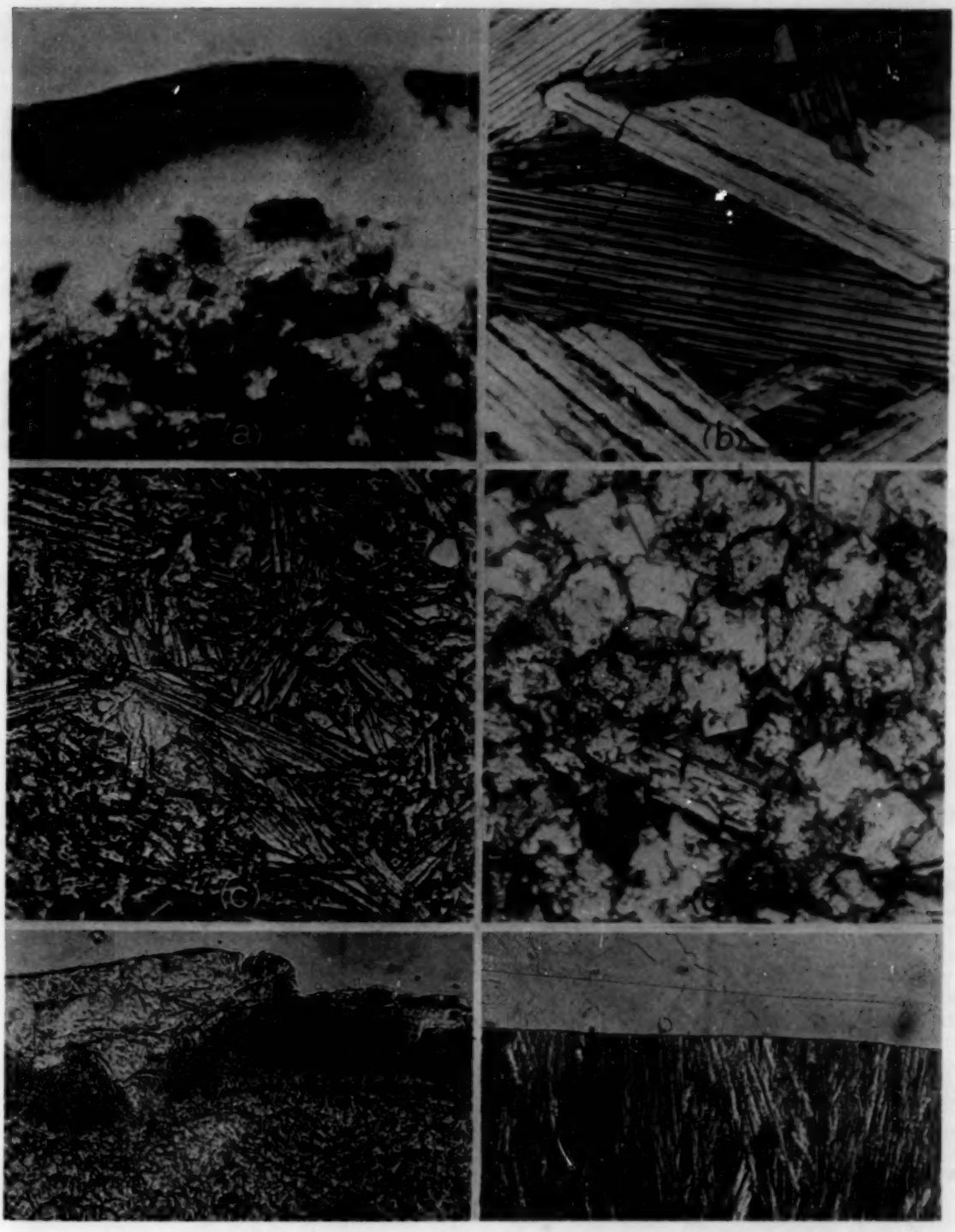

FIG. 1.—(*a*) Thin section of interface of clay flux block and a soda-lime glass (75×), crossed Nicols, selenite plate (note mullite devitrification, iron stain, and residual clay particles); (*b*) thin section of microstructure of Monofrax H (150×), crossed Nicols, selenite plate; (*c*) thin section of Monofrax H, showing closely packed twinned beta-alumina crystals (75×), transmitted polarized light; (*d*) thin section of Monofrax K (75×), crossed Nicols, selenite plate; (*e*) thin section of fused-quartz test block and soda-lime glass (150×) (note devitrification at interface); (*f*) thin section of interface of fusion-cast aluminum-silicate and borosilicate glass (75×) (note flow lines of glass, with different refractive indices).

IV. Intermediate Series of Tests

The most promising compositions, as determined by small-scale tests, were then tested. The shapes used were those of larger blocks, and a commercial day tank was constructed entirely of these cast blocks except for certain refractories to be used for comparison. After this tank was operated for thirteen months, it was torn down and rebuilt with other compositions and modifications, although all of the cast blocks were in excellent shape. The rebuilt day tank with the new compositions was in operation on a variety of glasses for about three years.

Shortly after the first day-tank test was started, individual blocks or panels of the preferred compositions were installed in continuous tanks being operated in different plants under a great variety of conditions.

V. Commercial Application

The change from the panel tests under commercial conditions to a more widespread use of these several compositions was a gradual process. Larger and larger installations were made, and the first continuous tank to be built entirely with Monofrax* was installed more than three years ago and was successfully operated on a special type of glass.

Three specific compositions, which will be referred to as Monofrax H, K, and L, each with its particular properties and applications, have emerged from these studies. The work has also shown definitely that no single fused-cast refractory is ideal for all types of glasses and all locations in a glass tank and that the proper refractory must be selected for specific positions.

VI. Descriptions of the Three Types

(1) Monofrax H

The crystalline composition of Monofrax H is known as beta-alumina. In its commercial form, it is almost entirely free of matrix material; probably no other commercial refractory consists so completely of a single crystalline phase. The crystal habit of this material is to form plates which are so closely packed and twinned that, although fusion-cast H refractory blocks are almost entirely free of matrix or interstitial material, they are characterized by great density. Their microstructure is shown in Fig. 1 (*b*) and (*c*). The parallel plates are characteristic, but these are caused by polysynthetic twinning rather than by cleavage. The earlier literature described beta-alumina as having prominent basal cleavage, but the writers agree with Barlett,[1] who stated that no cleavage was to be observed petrographically.

Although beta-alumina has been reported to be unstable under certain laboratory conditions, it has proved to be quite stable in commercial service under a wide range of furnace conditions, where it occurs in the presence of alkali or alkaline earth oxides or of glasses containing these constituents. Any apprehension on this score may be definitely dismissed.

(2) Monofrax K

Type K fusion-cast high alumina refractory is made by fusing alumina with a minor amount of chromite. Microscopically, it consists of a form of alpha-alumina with a matrix of what may be chiefly chromite containing spinel. Figure 1 (*d*) shows a typical microstructure, the prevailing alpha-alumina crystals being plainly evident.

(3) Monofrax L

Monofrax L is a composition of crystalline alumina, modified by the presence of small amounts of silica, titania, and alkaline-earth oxides which alter the physical structure and casting properties. The alumina crystals occur in two petrographic generations, the predominating form being the primary phase (alpha-alumina) crystals that form the body of the refractory. The secondary alumina is contained in the intercrystalline matrix.

(4) Comparison of H, K, and L

When large sections of these types of Monofrax are observed, they are found to be characterized by three distinct types of structure.

Type H is dense throughout, there are few pores or holes, and the section is free of pipes.

Type K is free of pipes, but it contains evenly distributed, sealed pores.

Type L is dense and quite free of pores, but it often shows some piping near one face of the block.

(5) Chemical Composition of H, L, and K

Type H is exceptionally free of ingredients that could cause contamination or discoloration in glass, the total ingredients other than alumina and soda being less than 0.5%, of which the major portion is silica. It is probably the purest refractory product commercially obtainable, particularly from the viewpoint of the glass technologist.

Type L is characterized by a high percentage of alumina which, as has been indicated, is present chiefly as alpha-alumina. This high content of crystalline alpha-alumina results in a very slow rate of corrosion so that the amount of iron and titania introduced into the glass is insignificant.

A casual consideration of the chrome content of type K might indicate it to be an undesirable material when it is subjected to the corrosion of molten glass. Tests, however, show it to have a very slow rate of corrosion in the presence of all commercial glasses so that the color effect of the iron and chromic oxide is quite negligible. Because the usual glass-batch ingredient and other refractories are free of chromium, the chromium in the glass produced in a tank containing type K refractory may serve both as a measure of the rate at which K is being corroded and of the amount of total oxide supplied to the glass by the refractory. In a sheet-glass tank, where an 18-inch depth of K

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* Monofrax is a registered trade mark for cast alumina refractories.

[1] H. B. Barlett, "Occurrence and Properties of Crystalline Alumina in Silicate Melts," *Jour. Amer. Ceram. Soc.*, **15** [7] 361–64 (1932).

was used at the metal line in the melting end to beyond the neck, the chromium oxide content of the glass produced was 0.0008%. The corresponding increase in the content of iron oxide (of which there is also a certain amount in type K) furnished by the refractory to the glass would be on the order of 0.0006%.

(6) Physical Properties

The softening point in each type is well over 1700°C.; none shows any deformation under a load of 25 lb. per sq. in. at 1500°C. Even the K mix, which is the least resistant to spalling of the three types, withstands heat shock well, and the H and L mixes in this respect are definitely superior to K. This means, particularly with the H and L types, that it is feasible to bring a furnace up to operating temperature at a reasonable rate without using more care than would be dictated by good judgment in the operation of any furnace. Compared with many bonded refractories, the spalling resistance even of the H mix, of course, is decidedly lower.

Type H is unique in that it is readily translucent even to visible light, which has caused some concern because the redness of the outer face of the blocks was first taken to indicate a high temperature. As a matter of fact, H has the lowest thermal conductivity of the three types. Its weight per unit volume and its thermal expansion are also lower than those of its companion mixes.

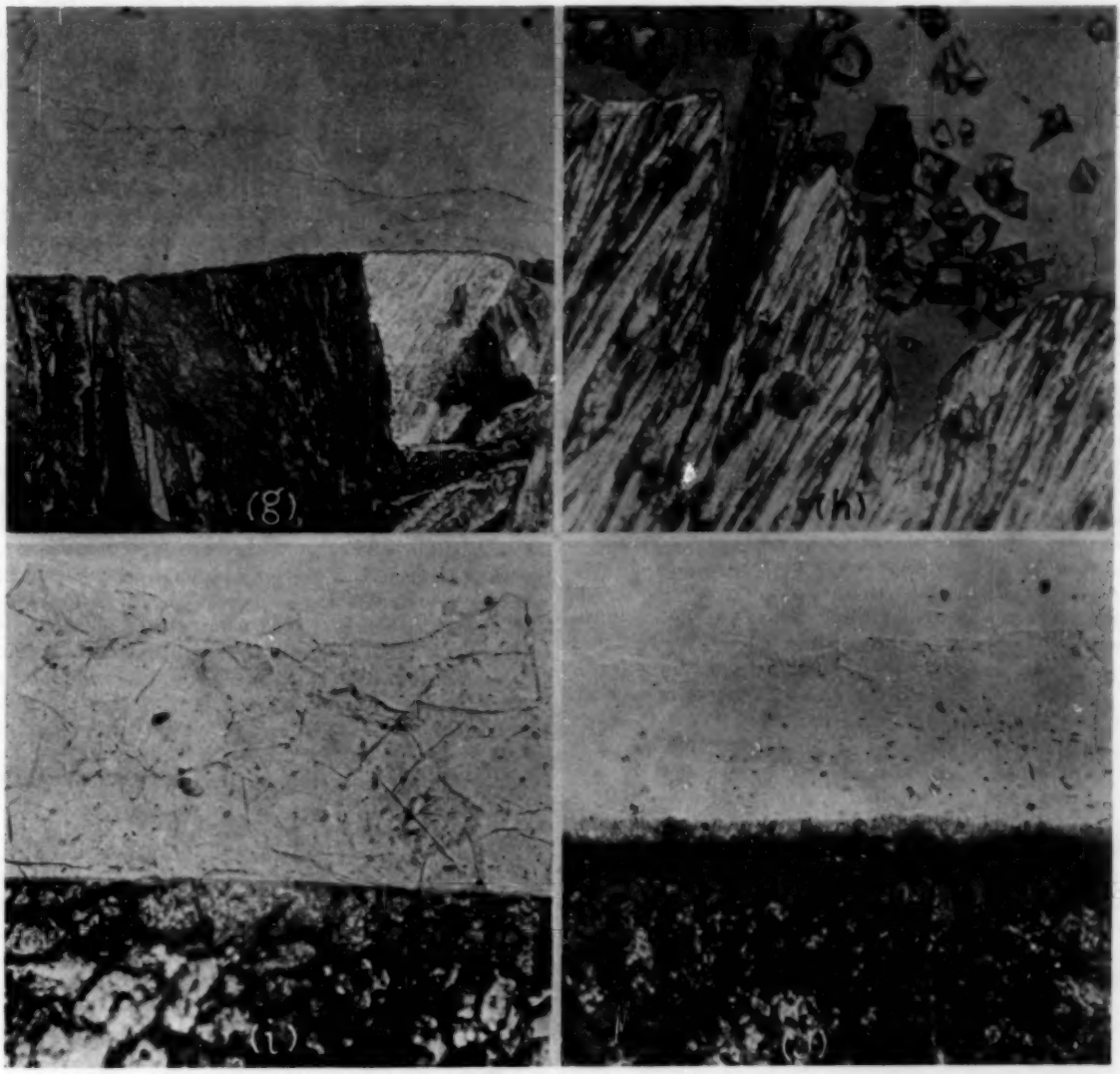

FIG. 2.—(*g*) Thin section of interface of Monofrax H and borosilicate glass (75×), crossed Nicols, selenite plate; (*h*) thin section of interface of a fusion-cast aluminum-silicate and a fluoride-type opal glass (150×), crossed Nicols, selenite plate; (*i*) interface of Monofrax L and a fluoride-type opal glass (150×), crossed Nicols, selenite plate; (*j*) thin section of interface of Monofrax K and soda-lime glass (150×), transmitted polarized light.

		Type		
		H	K	L
Thermal conductivity (cal./cc./sec./°C.) at 350°–850°C.		0.0059	0.0107	0.0137
Coefficient of expansion ($\times 10^6$)	25°–750°C.	5.69		7.00
	25°–1400°C.	7.44	9.33	8.79
Spalling test (No. of spalls at 700°C.)*		40	3	33
Lb./cu. ft. (avg.)		180	205	201

* The spalling test consisted in heating the entire test block to 700°C. in a "Globar" furnace, cooling to room temperature in air, and then replacing the test block in the furnace at 700°C. The spalling values are the number of cycles before breaking. The following comparable values for bonded commercial refractories may be cited to orient the reader's viewpoint: silica brick 1+, magnesia 7, and chromite 2.

VII. Interface Studies

One of the most interesting and helpful means of investigation at all stages of this development has been the examination of the glass-refractory interfaces of tested samples. This has proved (and continues to prove) to be the most useful means to determine the mechanism of corrosion; for example, it was determined early in these studies that microscopically there is usually no sharp line at the interface between soda-lime glass and clay flux blocks (see Fig. 1(*a*)). The nature of chemical solution may be detected in some cases by devitrification crystals; for example, in Fig. 1(*e*), quartz-glass refractory is dissolved and a large amount of cristobalite is precipitated, indicating the solution of such a large amount of silica that the interfacial glass had come to equilibrium in the high silica field of the Na_2O–CaO–SiO_2 system. This method of examination may be used therefore to determine whether mechanical or chemical processes are the chief cause of corrosion in any given instance. It may also show how corrosion for any single refractory will differ with different kinds of glass. Borosilicate glasses destroy refractories chiefly by chemical action. The glass-refractory interface generally shows clear glass, and penetration into the refractory is small.

Figure 1 (*f*) and Fig. 2 (*g*) show two refractories, both in contact with borosilicate glass. Figure 1(*f*) shows a fusion-cast aluminum silicate; Fig. 2(*g*) shows a type H fusion-cast alumina. The corrosion of the first was much greater than that of the H type, but the chief difference petrographically is in the absence of flow lines in the latter.

Soda-lime glasses destroy both by penetration and by chemical reaction. Fluoride opal glasses may destroy refractories both by chemical reaction and by mechanical disintegration through penetration. Figure 2(*h*) shows a cast aluminum-silicate refractory, and both penetration and solution by a fluoride glass may be observed. Figure 2(*i*) shows Monofrax L; the glass has not penetrated the refractory, but there has been chemical reaction.

If a refractory consists of more than one phase or of a grain and a bond, the relative corrosive reaction between the glass and each constituent may be learned. Monofrax K is shown in Fig. 2(*j*) in contact with a soda-lime glass. Penetration has been small, but the order of chemical solution has been differential. The matrix begins to dissolve first, but penetration is minimized because of its presence; the alpha-alumina crystals are dissolved next, but this solution is probably retarded because of the immiscibility of chromic oxide and silica,[2] and residual chromic oxide is the last part of the Monofrax K to dissolve in a highly siliceous glass. This cycle is continually repeated, but the steps follow each other so closely that at no time does the solution of the more easily dissolved constituent advance much beyond the highly refractory primary crystals of alpha-alumina.

VIII. Application

The purity and superior resistance to corrosion and erosion of Monofrax H make it an interesting material for the production of high-grade crystal glassware. Laboratory tests and commercial work show it to be well suited for borosilicate and fluoride-borosilicate glasses.

Because of the fact that it may be cast as a solid dense block with practically no voids and because of its resistance to "upward eating," Monofrax H is being used with all types of glasses for bridge walls and throats.

Monofrax K is the most resistant to corrosion and erosion of the three compositions, and it is being used for doghouses and for melting-end side walls even in fluoride tanks. Owing to its extreme resistance to erosion, there is less glass contamination than for the usual type refractories.

This is also the preferred composition, as shown by commercial tests for resistance to most metallurgical slags and rock and slag fusions, for the production of insulating wool.

Monofrax L is intermediate between H and K in purity. It is being used for the melting and refining ends and for bridge walls where the exceptional purity of H is not required.

The Carborundum Company
Niagara Falls, New York

[2] E. N. Bunting, "Phase Equilibria in the System Cr_2O_3–SiO_2," *Bur. Stand. Jour. Research*, **5** [2] 325–27 (1930); R. P. 203; *Ceram. Abs.*, **10** [1] 67 (1931).

CONCENTRATION OF FELDSPATHIC WASTE FROM A TITANIUM MINE NEAR ROSELAND, VIRGINIA*

By D. I. Smith, R. G. O'Meara, and T. N. McVay†

Abstract

The beneficiation of the feldspathic waste from a titanium mine near Roseland, Virginia, is discussed. This waste, which is mainly sodic plagioclase, quartz, and an iron-bearing mineral, gedrite, contains about 5.3% of Fe_2O_3. By magnetic concentration, 73% of the feed was recovered in a feldspar-quartz mixture with an iron content of 0.81% of Fe_2O_3. From this nonmagnetic product, between 85% and 90% of the feldspar with an iron content of 0.41 to 0.52% of Fe_2O_3 was recovered by agglomerate tabling and flotation. Examination of the feldspar concentrate, however, showed that iron stains and iron-bearing impurities of microscopic size in the feldspar prevented the separation of a feldspar concentrate with less than 0.36% of Fe_2O_3.

I. Introduction

Feldspar is one of the most common minerals in crystalline rocks, but its abundance alone does not assure a supply of feldspar suitable for the ceramic industry. Industrial feldspar is obtained from feldspathic rocks in which the coarse crystalline structure favors selective mining and hand picking. Deposits of this type are being depleted rapidly, and there is little probability that many new occurrences favorably situated for the consumer remain to be discovered. Future supplies of feldspar, therefore, may have to come from the present feldspar mine-waste or from the widely distributed granites and related rocks in which feldspar is finely disseminated. Feldspathic tailings from a former milling operation likewise may be an attractive source of feldspar because of minimized mining and grinding costs. The separation of feldspar from quartz and some of the associated impurities has been demonstrated,[1] but the rejection of still other impurities with which the feldspar may be associated presents a problem that may necessitate a different modification of the process for each mineral.

This paper describes the separation of feldspar in a mill tailing, hereafter referred to as waste, from a titanium mine in Nelson County near Roseland, Virginia. The feldspar is the same type contained in the feldspathic product known as aplite and mined at the present time in Nelson County. The objective of the research was to develop a method of beneficiation by which a −20-mesh feldspar suitable for the glass trade could be recovered. The study of the composition and structure of the waste and the results of laboratory concentration tests using magnetic separation, agglomerate tabling, and flotation are described.

II. Description of the Waste

The waste was rejected in milling a titanium ore from a mine in the rutile area of Nelson County near Roseland. These deposits, called "nelsonite," are a series of dikelike bodies that are syenite rocks containing titanium and ferromagnesian minerals. In the milling, the ore was crushed through 8-mesh and concentrated on tables to recover the titanium minerals.

The waste contains about 60% of sodic plagioclase, 14% of quartz, and 26% of material that is mainly gedrite, but it also includes minor amounts of ilmenite, rutile, zoisite, apatite, and muscovite. This waste assays 5.31% of Fe_2O_3; most of the latter occurs as gedrite, but some of it is present in the other accessory minerals and as alteration products or stains on the mineral grains. Most of the feldspar particles contain inclusions of plates of apatite and of microscopic specks of zoisite and other alteration products. Some interlocking of minerals in −20- + 48-mesh particles also was observed. A screen analysis of the tailing showed no important size segregation of the iron-bearing minerals.

A sink-and-float separation of the waste with liquids of different specific gravities indicated that any method of concentration depending on differences in specific gravity would be unsatisfactory. Agglomerate tabling and flotation, alone and preceded by magnetic concentration, were considered next as possible treatments that would separate the feldspar with the proper size ratio for the trade requirements.

It should be noted at this point that agglomerate tabling is the table concentration of minerals selectively oiled so that the particles congregate in floccules which, owing to film suspension and low apparent specific gravity, float across to the tailing side of the table, whereas the unoiled minerals move to the concentrate end.

By agglomerate tabling and flotation following the procedure and by the use of cationic reagents,[1] much of the iron-bearing material in the waste was depressed with the quartz, but the feldspar still contained appre-

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† D. I. Smith, graduate student, University of Alabama; R. G. O'Meara, nonmetals engineer, Bureau of Mines, Tuscaloosa, Ala.; and T. N. McVay, professor of Ceramics and Mineralogy, University of Alabama.

[1] R. G. O'Meara, J. E. Norman, and W. E. Hammond, "Froth Flotation and Agglomerate Tabling of Feldspars," *Bull. Amer. Ceram. Soc.*, **18** [8] 286–92 (1939).

ciable iron. High-intensity magnetic concentration of the waste separated most of the iron-bearing minerals, but some particles with iron stains and inclusions remained in the nonmagnetic part. When, moreover, the usual agglomerate tabling and flotation procedure was applied to this nonmagnetic part of the waste, it failed to reject the iron-contaminated or locked grains. A modification of the usual agglomerate tabling and flotation procedure for separating feldspar therefore was necessary. In this modification, a two-step treatment was used in the agglomerate tabling, and a three-step treatment was used in the flotation. That is, the usual agglomerate tabling with cationic collectors was preceded by agglomerate tabling with anionic collectors, and the usual flotation with cationic collectors was preceded first by flotation with cationic collectors and then by flotation with anionic collectors. In modifications of the usual procedure,[1] all of the collectors used were of the cationic type. As the two types of collectors are different, the anionic being suitable for basic minerals and the cationic for acidic minerals, these two-step and three-step separations have considerable interest. In the following treatment, the waste was crushed through 10-mesh, and the magnetic material was rejected. The nonmagnetic material was then crushed through 20-mesh and screened on 48-mesh. The + 48-mesh was agglomerated and tabled, and the −48-mesh was treated by froth flotation.

III. Magnetic Separation

The −10-mesh waste was treated on a two-roll, high-intensity magnetic separator. By magnetic concentration, a feldspar-quartz mixture with an iron content of 0.81% of Fe_2O_3 was separated. The recovery of this material was 73%. The details of the test are shown in Table I.

TABLE I

MAGNETIC CONCENTRATION OF −10-MESH WASTE

Product	Weight (%)	Assay Fe_2O_3 (%)	Distribution Fe_2O_3 (%)
Nonmagnetic (feldspar-quartz) concentrate	73.0	0.81	11.1
Magnetic tailing	27.0	17.48	88.9
Composite	100.0	5.31	100.0

The magnetic tailing, which was mainly gedrite, contained some ilmenite, rutile, zoisite, and stained grains of quartz and feldspar. Examination of the nonmagnetic product showed that the 0.81% of Fe_2O_3 was due partly to free but chiefly to interlocked or included iron-bearing minerals of microscopic size. This nonmagnetic quartz-feldspar mixture was crushed through 20-mesh and screened on 48-mesh. About 90% of the ground product was coarser than 48-mesh. The + 48-mesh material was agglomerated and tabled, and the − 48-mesh part was separated by flotation.

IV. Agglomerate Tabling

The − 20- + 48-mesh nonmagnetic product was first wet with water to make a pulp of about 60% of solids. To separate the feldspar from both the quartz- and iron-contaminated grains, two agglomerate tabling operations were required. In each, the reagents and oil were added for agglomeration, which was followed by tabling. First, an anionic collector was employed to remove the iron-stained material, and the customary cationic collector was then used to remove the feldspar. The results of a typical test are given in Table II.

The feldspar concentrate contained 2% of quartz and 0.52% of Fe_2O_3, and the recovery was nearly 95%.

V. Flotation

In the flotation, as in the agglomerate tabling, a combination of three successive flotation treatments was used to separate the feldspar from the quartz, the iron-bearing minerals, and the claylike alteration products. The − 48-mesh nonmagnetic product was mixed with water to form a pulp of about 20% of solids. To reduce the consumption of reagents in the flotation of the feldspar, the slime was removed first by flotation with a cationic collector, such as a short-chain amine. (The claylike alteration products could have been partly removed by simple decantation.) The iron-contaminated grains were floated next with an anionic reagent. Succeeding this second step, the feldspar was floated with the customary cationic reagents. The results of a test using this combination of treatments are given in Table III.

The feldspar concentrate, containing 1% of quartz and 0.41% of Fe_2O_3, was 63.1% of the flotation feed and represented a recovery of 81.7%. A lower iron content

TABLE II

AGGLOMERATE TABLING TEST OF NONMAGNETIC WASTE

Reagent	Lb./ton of feed: Iron separation	Lb./ton of feed: Feldspar separation
Sodium oleate	2.00	
Hydrofluoric acid		4.00
Lauryl amine hydrochloride (DP 243)		2.00
Crude diesel oil	4.00	4.00

Product	Weight (%)	Assay (%): Fe_2O_3	Assay (%): Feldspar	Assay (%): Quartz	Distribution (%): Fe_2O_3	Distribution (%): Feldspar	Distribution (%): Quartz
Iron concentrate	10.3	4.08	29.0	16.0	48.2	4.0	8.5
Feldspar concentrate	73.2	0.52	98.0	2.0	43.7	94.9	7.5
Quartz tailing	16.5	0.45	4.6	95.4	8.1	1.1	84.0
Composite	100.0	0.87	75.6	18.8	100.0	100.0	100.0

TABLE III

FLOTATION TEST ON NONMAGNETIC WASTE

Reagent	Lb./ton of feed: Slime flotation	Iron flotation	Feldspar flotation
Tributyl amine	0.33		
Sodium oleate		2.0	
Hydrofluoric acid			4.0
Lauryl amine hydrochloride (DP 243)			2.0

Product	Weight (%)	Assay (%): Fe_2O_3	Feldspar	Quartz	Distribution (%): Fe_2O_3	Feldspar	Quartz
Slime concentrate	7.3	2.82	75.3	7.1	60.9	18.2	7.0
Iron concentrate	11.6						
Feldspar concentrate	63.1	0.41	99.0	1.0	29.9	81.7	3.2
Quartz tailing	18.0	0.47	1.4	98.6	9.2	0.1	89.8
Composite	100.0	0.81	77.9	18.6	100.0	100.0	100.0

was obtained in the flotation than in the agglomerate concentrate because of less locking in the −48-mesh sizes of the feldspar.

Examination of the feldspar concentrate with a high-intensity analytical magnet showed that a few particles of iron-bearing minerals were present. Removal of these impurities in this manner reduced the iron content of the feldspar product from 0.41 to 0.36% of Fe_2O_3, which indicates that the flotation process removes most of the free iron-bearing impurities remaining in the nonmagnetic product from the previous magnetic concentration of the waste. The intimate association of the iron-bearing mineral, zoisite, with the feldspar and a few iron oxide-coated feldspar grains, however, prohibited the iron content of the feldspar product from being reduced to less than 0.36% of Fe_2O_3.

VI. Summation of Results

By the combined treatment of magnetic concentration, agglomerate tabling, and flotation, most of the clean feldspar was recovered, and most of the iron other than that locked with or staining the feldspar particles was rejected. Table IV summarizes the results, showing the rejection of the iron and concentration of the feldspar in each step.

TABLE IV

ANALYSIS OF BENEFICIATED PRODUCTS

Product	Assay (%): Fe_2O_3	Feldspar	Quartz
As received	5.31	60.3	13.9
Nonmagnetic concentrate	0.81	77.2	18.6
Flotation feldspar concentrate	0.41	99.0	1.0
Agglomerate feldspar concentrate	0.52	98.0	2.0

Although the association of minerals in the waste prevented the separation of a feldspar with as low iron content as desirable, the modification of the usual method for separating feldspar from quartz was adaptable and may be satisfactory for ores that are less complex.

UNIVERSITY OF ALABAMA
UNIVERSITY, ALABAMA

DECALCOMANIA: PROPOSED DEVELOPMENT*

BY ARTHUR S. WATTS

ABSTRACT

The greatest fault of overglaze decalcomania is the lack of resistance to solution and abrasion, which is due chiefly to the fluxes used for adherence to the glazed surfaces and for the development of brilliancy. With our increasing knowledge of silicate eutectics, these properties may be greatly improved. Various color fluxes are tested and several experimental fluxes with improved chemical resistance are reported. The possibilities of overglaze colors and decalcomania that mature at 1500° and 1750°F. are also discussed, and some data are furnished.

I. Introduction

Although the United States dinnerware manufacturer need not fear foreign competition at the close of the present war because of the quality of the body or the glaze, the dealer, as well as the public, is still far from satisfied with overglaze decalcomania. The question is how can the resistance to wear and solution of these overglaze decorations be improved. The flux normally used is a lead borosilicate, which alone shows relatively little resistance to wear or solution. The colors, moreover,

* Presented at the Forty-Second Annual Meeting, The American Ceramic Society, Toronto, Canada, April 9, 1940 (White Wares Division). Received April 9, 1940.

cannot be expected to display more resistance than the vehicle by which they are surrounded and bonded on the glaze surface. The only possible exception would be where the colorant dissolves in the flux and raises its resistance. A study of these fluxes seems to offer a practical remedy to these problems.

II. The Investigation

The following glasses were melted and applied as thin glazes to china biscuit which had been thoroughly vitrified:

Glaze No.			
1	PbO	0.5 SiO_2	
2	"	0.25 B_2O_3	0.60 SiO_2
3	"	0.15 B_2O_3 0.10 Al_2O_3	1.12 "
4	"	0.125 B_2O_3 0.125 Al_2O_3	1.25 "
5	"	0.25 Al_2O_3	1.9 "

After firing for thirty minutes, the following maturing temperatures were reached for each glass: No. 1 1300°F., No. 2 1350°F., No. 3 1450°F., No. 4 1450°F., and No. 5 1550°F. All of the glazes were then fired in thirty minutes to 1550°F. and subjected to a 0.25% solution of trisodium phosphate for eight hours at 200°F. The following results were obtained: Nos. 1 and 2 definitely etched; No. 3 slightly etched; No. 4, no visible etching but iridescent spots indicating chemical action; No. 5 no attack.

A new set of glazes was prepared as follows:

Glaze No.			
P1	PbO	0.15 Al_2O_3	1.00 SiO_2
P2	"	" "	1.50 "
P3	"	" "	1.75 "
P4	"	" "	2.00 "

These glazes were applied and fired at 1500°F. in thirty minutes and at 1800°F. in forty-five minutes. The same tests were applied as in the first glaze series with the following results:

No. P1 at 1500°F. etched; at 1800°F. slight etching.

No. P2 at 1500°F. less etched; at 1800°F. very slight etching.

No. P3 at 1500°F. trace of etching; at 1800°F. no visible etching but slight loss of brilliancy.

No. P4 at 1500°F. slight loss of brilliancy; at 1800°F. no etching or loss of brilliancy.

Thus with 0.15 of Al_2O_3 and 1.75 of SiO_2, the attack is reduced to a marked degree, and with further increase of SiO_2 the attack is zero.

A third glaze series was tested, using the following compositions:

Glaze No.			
P6	PbO	0.10 Al_2O_3	2.00 SiO_2
P7	"	0.254 "	1.91 "
P8	"	0.30 "	1.91 "
P9	"	0.35 "	1.91 "

Glaze P7 was chosen because it was reported by Lu[1] as the PbO-Al_2O_3-SiO_2 eutectic, and the silica content of this member was continued in Nos. P8 and P9 to disclose the effect of alumina on the chemical resistance of this type of glass.

These glasses were applied and fired at 1700°F. in forty minutes and at 1900°F. in fifty minutes. The test results were as follows:

No. P6 at 1700°F. no etching, but slight loss of brilliancy; at 1900°F. no attack of any sort.

No. P7 at 1700°F. no attack, but glass showed a slight lack of fluidity on the trials; at 1900°F. perfect maturity and no attack.

No. P8 at 1700°F. no attack, but same lack of maturity as evidenced by No. P7; at 1900°F. no attack and perfect maturity.

No. P9 at 1700°F. evidence of immaturity more pronounced, but no evidence of attack; at 1900°F., no attack but some evidence of immaturity.

The increase in Al_2O_3 apparently is limited by the increase in viscosity imparted to the glass.

III. Conclusions

This study indicates the futility of employing lead borosilicates as fluxes for low-temperature colors and the definite promise for fluxes containing even a small amount of alumina. The benefits of an increased silica content are also definitely indicated.

The next step is to determine the limits of sodium oxide and boron oxide, which may be introduced without the sacrifice of chemical resistance.

The development of decalçomania colors which resist chemical attack undoubtedly will involve some increase in the firing temperature, but if this increase can be kept below 1600°F., there should be no serious loss of color; furthermore, with modern fritted glazes, no spit-out should be encountered. The only serious problem will be the adjustment of metallic gold and platinum decorations to the increased firing temperature.

Department of Ceramic Engineering
Ohio State University
Columbus, Ohio

[1] K. C. Lu, "Deformation Study of Various Alumino-Silicates and Borosilicates," *Jour. Amer. Ceram. Soc.*, 9 [1] 29–54 (1926).

CERAMIC ABSTRACTS

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AMERICAN CERAMIC SOCIETY

Ross C. Purdy, Editor

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November, 1940
19—11

Abrasives

Cutting the cost of cutting tools. D. G. Baird. *Mill & Factory*, **26** [2] 65–67, 178, 180, 182 (1940).—Having 2400 standard cutting tools and 1100 special tools in use, the Plymouth Division of the Chrysler Corp. knows how many pieces per grind, total grindings of tool, number of pieces each tool is expected to produce before salvage, cost of tool per 1000 pieces produced, etc. This information is the result of making tests and keeping records. D.A.B.

Drilling diamond dies. Anon. *Phillips Tech. Rev.*, **5** [1] 14 (1940).—In the Phillips factory for drilling diamonds, considered one of the largest of its kind in the world, dies for drawing wire are made with diameters from 10 microns up. Part of the production is destined for use in the other departments, viz., for drawing wire of tungsten, molybdenum, and other metals. The diamonds which are made into dies are first cut off flat on the two opposite sides of the future bore. Facets are then ground in two mutually perpendicular planes parallel to the direction of the bore, which makes it possible to follow the drilling process and to control it continually by means of a microscope. The diamond so prepared is fastened into a holder. The drilling is done with a needle of a special shape which is allowed to take up diamond dust mixed with oil in the pores of its surface. The bore must be given a very definite shape and polish for each material to be drawn in order that the die may have a long life. On the side where the wire leaves the die, the drawing channel opens out into a wider depression (clearly shown in a photomicrograph magnified 120 times). Illustrated. H.K.R.

Modernization to improve production. E. L. Cady. *Mill & Factory*, **26** [3] 51–60, 178 (1940).—C. discusses the effect of modernization in improving production at the Precision Grinding Wheel Co. Its policy of maintenance, clerical routine, industrial relations, control, abrasive processes, and the handfacing of large wheels are described. Illustrated. D.A.B.

Modernization in a self-contained plant. E. L. Cady. *Mill & Factory*, **26** [1] 51–62 (1940).—C. describes the machinery and general operations of the Gillette Safety Razor Co.'s plant at Boston, Mass. Starting with the coil blanks, he describes the steps of perforating, degreasing, hardening, tempering, etching, lacquering, grinding, honing, stropping, separating the blades from the coil strip, wrapping, and packing. Illustrated. D.A.B.

Structure of polished metal surfaces. S. Dobinski. *Physik. Z.*, **40** [7] 232–34 (1939).—D. discusses a paper by E. Plessing (*ibid.*, **39**, 618 (1938)) on the bending of electrons on polished metal surfaces. From the electron interference pictures, it was concluded that these surfaces, either polished in the air or under benzol, were oxidized by chemical reaction. Plessing, in remarks adjoining this paper, states that if oxidation had taken place, crystallization should show on the surface layer upon heating these metal mirrors in vacuum at 10^{-3} mm. Hg at 600°C. Iron must thereby be excluded. Interference pictures of heated copper and nickel surfaces, however, agree with those of the pure metals. No final conclusion regarding the difference in results found by these two investigators is reached. L.E.T.

Testing and grading fine abrasives. E. L. Hemingway. *S. A. E. Jour.*, **47**, 332–41 (1940).—A new method was developed because of the apparent inability of manufacturers to grade properly the hardness of the bond in bonded abrasives to be used in Superfinishing machines. For this a porous, vitrified stone of about 320- to 600-grit size is used. When first applied, the grit is sharp; it cuts off the peaks of hills on the surface, and the lubricant washes off loose metal and grit. This varies continuously until the stone is glazed and riding on the film of lubricant. Too hard a bond stops the cutting action too early, while too soft a bond prolongs the cutting action. Preliminary tests were made with a Rockwell hardness tester, a diamond point, and 60 kgm. load, reading the B scale. About 1500 tests were made on 402 stones of 24 lots. Only 14 lots were uniform and, of these, only four were correctly graded. Single stones were often not uniform. Results from this hardness tester agreed perfectly with those of stones in actual use. A $\frac{1}{8}$-in. steel ball and a 60-kgm. load were the best combination for the tester. A graph was constructed of steel hardness vs. stone hardness for standard conditions of

finishing. This has been used satisfactorily for five months. Stones should be tested on both ends and in the center. For grits much coarser than 320, some tests suggest a $^1/_2$-in. ball and 150-kgm. load. A discussion is included. W.D.F.

PATENTS

Abrasive articles and method of manufacturing. A. L. BALL (Carborundum Co.). U. S. 2,213,332, Sept. 3, 1940 (Nov. 29, 1935; renewed Nov. 2, 1938).—The steps in the method of making an abrasive article comprise wetting abrasive particles with an alkaline silicate solution, mixing the coated particles with a heat-hardenable resin in finely divided form, forming an article from the mixture, and heating the article to harden the resin.

Abrasive belt. E. P. DAHLSTROM (Carborundum Co.). U. S. 2,215,210, Sept. 17, 1940 (Dec. 9, 1938).

Abrasive throwing or impelling apparatus. L. D. PEIK (American Foundry Equipment Co.). U. S. 2,212,451, Aug. 20, 1940 (Aug. 14, 1933; March 27, 1940).

Abrasive wheels for surface, former, and other grinding. J. H. FLETCHER, MITCHELL'S EMERY WHEEL CO., LTD., D. M. ANDERSON, AND GEAR GRINDING CO., LTD. Brit. 523,879, Aug. 8, 1940 (Feb. 13, 1939).

Apparatus for surfacing metals. H. R. HERCHENRIDER (Minnesota Mining & Mfg. Co.). U. S. 2,214,373, Sept. 10, 1940 (Oct. 30, 1937).

Automatic machine for grinding metal-strip material. MOND NICKEL CO., LTD. Brit. 523,916, Aug. 8, 1940 (Aug. 26, 1938).

Automatic machine for grinding millings, etc. SÄCHSISCHE ARMATUREN-FAB. W. MICHALK & SOHN. Ger. 684,274, Nov. 2, 1939 (Jan. 9, 1937); XII/67*a*. 1.—The grinding wheel moves freely into the notched spaces, and with a slight swinging motion of the workpiece around its axis it covers the surface outline. The workpiece carrier is pushed to and fro in the workpiece axial direction after each change; it has an arm stand under weight or spring tension which moves on a fixed guiding track regulable in two directions and controls the swinging motion of the workpiece. D.A.B.

Bonded abrasive. R. C. SWAIN AND D. W. LIGHT (American Cyanamid Co.). U. S. 2,215,380, Sept. 17, 1940 (March 10, 1939).—An abrasive article comprises particles of abrasive and an aminotriazine-aldehyde resin cured in contact therewith.

Combination tool head and grinding machine. W. N. CHITTENDEN (Cincinnati Milling Machine Co.). U. S. 2,212,855, Aug. 27, 1940 (Oct. 6, 1937).

Device for dressing screw-thread grinding disks. HANS BRENDEL AND ERICH BUCHHOLZ (Bauer & Schaurte). U. S. 2,213,665, Sept. 3, 1940 (April 2, 1938).

Device for honing cylindrical surfaces. H. S. INDGE (Norton Co.). U. S. 2,213,027, Aug. 27, 1940 (Oct. 22, 1938).

File or like grinding mechanism. L. J. FAULDER. U. S. 2,212,999, Aug. 27, 1940 (Oct. 14, 1937).

Finished surfaces and method and apparatus for finishing surfaces. CHRYSLER CORP. Brit. 524,519, Aug. 21, 1940 (July 29, 1938).

Finishing surfaces by abrading. CHRYSLER CORP. Brit. 524,518, Aug. 21, 1940 (July 16, 1938). Brit. 524,520, Aug. 21, 1940 (Sept. 23, 1938).

Grinding gauge. PRENTICE CONRADSON (Conrad M. Conradson). U. S. 2,212,511, Aug. 27, 1940 (Aug. 1, 1938).

Grinding machine. KURT ZWICK (Friedrich Deckel). U. S. 2,213,756, Sept. 3, 1940 (March 17, 1939).

Grinding and polishing stone. HORBACH & SCHMITZ. Ger. 679,919, July 27, 1939 (July 5, 1938); VI/80*b*. 11.—A grinding and polishing stone consists of a compact mixture of quartz, pumice or pumice powder, and binding agent. Magnesia cement is employed as the binding agent. D.A.B.

Grindstone. W. E. DANBACK (Cleveland Quarries Co.). U. S. 2,213,065, Aug. 27, 1940 (Jan. 24, 1939).

Lap grinding machines. W. ARMSTRONG. Brit. 523,995, Aug. 8, 1940 (Jan. 19, 1939).

Lens grinder. J. H. MARTIN. U. S. 2,212,179, Aug. 20, 1940 (Dec. 20, 1938).

Locomotive and car wheel grinding machine. R. G. MCGOWAN. U. S. 2,215,403, Sept. 17, 1940 (Oct. 19, 1939).

Machine for grinding or sharpening knife blades, etc. BRITISH EMULSIFIERS, LTD., AND T. CURZON. Brit. 523,868, Aug. 8, 1940 (Jan. 17, 1939). Brit. 524,832, Aug. 28, 1940 (Feb. 8, 1939).

Machining tapered surfaces. MICROMATIC HONE CORP. Brit. 524,369, Aug. 14, 1940 (Feb. 3, 1938).

Means for dressing grinding wheels. E. L. MEESON. Brit. 523,963, Aug. 8, 1940 (Jan. 18, 1939).

Method for fine and precise grinding, lapping, etc., of level surfaces. HEINRICH ROSSBACHER (Julius Pintsch Kom.-Ges.). Ger. 686,568, Dec. 14, 1939 (March 28, 1939); XII/67*a*. 13.—Fine, precise work is done with a machine provided with a revolving workpiece holder and a rotating tool (grinding wheel) which move in counter directions. The grinding wheel (lapping wheel, etc.) and the workpiece holder are put into uniform, synchronous rotation, and the grinding, etc., process is started and performed by reducing the number of revolutions of one of the two revolving units. The process is terminated by increasing the number of revolutions of the unit whose speed was decreased to correspond with the number of revolutions of the other part. D.A.B.

Piston grinding machine. H. A. SILVEN (Norton Co.). U. S. 2,213,030, Aug. 27, 1940 (May 3, 1939).

Pneumatic polishing and abrading machine. ERNST AHLSKOG. U. S. 2,214,189, Sept. 10, 1940 (Dec. 3, 1938).

Polishing disk. C. F. SCHLEGEL (Schlegel Mfg. Co.). U. S. 2,214,351, Sept. 10, 1940 (June 5, 1937).

Producing a grinding wheel. L. H. MILLIGAN AND R. H. LOMBARD (Deutsche Norton-Ges. m. b. H.). Ger. 679,918, July 27, 1939 (Oct. 15, 1937); VI/80*b*. 11.—An abrasive ring of high-grade grain, such as diamond grain, is joined with a ring of low-value grains to form a unit by pressing and binding. A mixture of high-grade abrasive particles and the binding agent is filled in around a prepressed nuclear disk of a mixture of low-value grains and binding agent in the pressing form and pressed together on the circumference of the nuclear disk by a radially acting pressure. D.A.B.

Production of abrasive material. R. C. BENNER AND R. L. MELTON (Carborundum Co.). U. S. 21,552, Sept. 10, 1940 (May 9, 1940); reissue of original 2,078,831 (*Ceram. Abs.*, **16** [7] 195 (1937)).—The method of making abrasive-coated products comprises coating a backing material with a liquid resin and applying abrasive grains and a catalyst for curing the resin to the resin-coated side of the backing to cause the resin to solidify and attach the abrasive grains firmly to the backing.

Production of metal components by grinding. BRISTOL AEROPLANE CO., LTD., F. W. WHITEHEAD, COVENTRY GAUGE & TOOL CO., LTD., AND S. J. HARLEY. Brit. 524,567, Aug. 21, 1940 (Feb. 1, 1939).

Saw grinder. A. W. SHAW. U. S. 2,213,413, Sept. 3, 1940 (June 6, 1938).

Screw-grinding processes. H. LINDNER. Brit. 524,305, Aug. 14, 1940 (Nov. 29, 1938).

Art and Archeology

Ancient Chinese kiln site. MALCOLM F. FARLEY. *Asia*, **40**, 496–501 (1940).—The kiln dump covers an area up to a mile long and a quarter of a mile wide. An excellent white clay is still obtainable there. Celadon ware was found with both light-green and olive-green glazes. A Ying Ch'ing variety closely resembles this type except that it lacks a slight reddening on the base. A Ting type is the finest early porcelain made. The Earth Ting is buff or straw colored with a colorless glaze. The temmoku type has a buff-gray body with a brownish glaze that does not

cover the base. Tall, narrow, heavy stoneware jars 8 to 12 in. high were also found. The rims of the bowls are often of double thickness to protect them from breakage. Frequently, there are no decorations; those found are usually hastily executed and crude but vigorous. Few museums have ware from this site. See "Fukien . . .," *Ceram. Abs.*, 19 [8] 181 (1940). W.D.F.

Athenian toilet box. G. M. A. RICHTER. *Bull. Metropolitan Mus. Art*, 35 [8] 157–59 (1940).—The Museum has just acquired an Athenian terra-cotta toilet box (pyxis or kylichnis) painted in polychrome (black and diluted glaze, purplish red, drab, and yellow ocher) on a white ground. The painting on the box is remarkable for its delicacy of drawing and harmonious composition. Six women, having Nereids' names, are represented in everyday scenes in the home, such as putting away clothes, dressing, and playing with pet birds. Women in their homes was a favorite subject with Athenian vase painters, but the grace and delicacy of both color and composition make this painting especially fine. The painting on the lid of the box has almost entirely disappeared but suggests an outdoor scene and figures that probably represent Muses. The paintings may be dated about the time of the famous Eretrian painter (430–425 B.C.), but the style resembles the work of the painter of a white-ground jug with Athena and Hercules in the British Museum. These two works are the only known examples of this painter of about the time of the Parthenon pediments. Illustrated. A.A.A.

Ceramic treasures of the Civic Hospitals of Genoa. G. MORAZZONI. *Ceramica*, 2 [4] 133–48 (1940).—The rare collection of antique Italian vases and pitchers acquired by the two hospitals of Genoa during the past centuries is illustrated and described. The pieces are lavishly decorated and many picture historical, mythical, and biblical scenes. The techniques of decoration employed by the most renowned of the artists are discussed. M.V.C.

Cincinnati Pottery Club. CLARA CHIPMAN NEWTON. *Bull. Amer. Ceram. Soc.*, 19 [9] 345–53 (1940); see *ibid.*, 18 [11] 443–46 (1939).

Contemporary Swedish and Danish decorative arts. PRESTON REMINGTON. *Bull. Metropolitan Mus. Art*, 35 [5] 103–106 (1940).—Seven examples of modern Swedish decorative art and three of modern Danish art have been acquired by the Museum from Swedish and Danish exhibits at the New York World's Fair. Two distinguished vases of Ariel glass from the Orrefors glassworks, one designed by Viktor Lindstrand, are illustrated. A tall crystal vase from the Kosta glassworks, designed by Elis Bergh; a handsome high-sided crystal bowl designed by Edvin Ollers and executed at the Åfors glassworks; and a beautiful smoky crystal vase from the Strömberg glassworks, designed by Gerda Strömberg, are included. A large earthenware bowl from the Gävle Porcelain Manufactory was designed by Arthur Carlson Percy, an outstanding Swedish designer. An unusual earthenware bowl from the Royal Copenhagen Porcelain Manufactory was designed by A. Malinowski and glazed by H. Madslund. This bowl has the *solfatara* glaze, a recent invention of the manufacturer, produced by the accidental effects obtained when reddish brown and greenish yellow glazes are superimposed over a warm translucent white basic glaze. See *Ceram. Abs.*, 19 [10] 228–29 (1940). A.A.A.

Faience broad collar of the 18th dynasty. AMBROSE LANSING. *Bull. Metropolitan Mus. Art*, 35 [3] 65–68 (1940).—Faience made by glazing a paste of ground quartz to simulate the colors of semiprecious stones was known throughout Egyptian history. Beads of the glazed faience have been found in graves of the Badarian period and date at least from the beginning of the 4th millenium B.C. This faience was also fashioned into vessels, tile, and figures of animals and human beings. The most elaborate pieces of jewelry worn by both men and women were broad collars. When not in fashion for ordinary wear, they continued to be an essential part of the burial costume. The custom of wearing several strings of beads around the neck probably developed the idea of stringing beads crosswise to keep the single strands in place. Faience collars were not in fashion for a time, but they were revived following the vogue for wearing collars made up of real flowers and leaves. The Museum possesses three of these fragile flower collars made up of concentric rows of leaves, flowers, and berries, the berries being alternated with groups of blue beads. The first floral faience collar sufficiently well preserved to leave no doubt as to the original arrangement of the beads and pendants was found in the tomb of Tutankhamen, although excavations have brought to light many other fragments as well as the pottery molds in which they were cast. Illustrated. A.A.A.

Gifts for the American Wing. JOSEPH DOWNS. *Bull. Metropolitan Mus. Art*, 35 [4] 90–92 (1940).—A cream-colored earthenware punch bowl decorated with American subjects has been given to the Museum by Mrs. J. Insley Blair. It was made and decorated with engravings at Liverpool about 1800, probably at Herculaneum, one of the local factories specializing in black-printed ware. The bowl is unusually large (14 in. in diameter and 6¼ in. high), and there are a number of transfer prints both inside and outside. The subjects commemorate the death of Washington and extol American freedom and prosperity. A ship under full sail carrying an American flag with sixteen stars helps to date the bowl prior to 1803. A.A.A.

Gift of European pottery. C. L. A. *Bull. Metropolitan Mus. Art*, 35 [8] 166 (1940).—Mrs. J. Insley Blair has given to the Museum a Delft pottery plate and three examples of English delftware of the 18th century. The Dutch plate, decorated with a dragon in blue, is a direct rendering of a simple Chinese theme, while the English pieces show differing expressions of the pseudo-Oriental designs then so popular. An English delftware plate (Bristol, about 1750) is illustrated. A.A.A.

Glass in Italian schools of art. ANON. *Vetro*, 2 [12] 454 (1939); *Jour. Soc. Glass Tech.*, 24 [102] 107A (1940).—Work in glass produced in Italian schools of art and displayed at an exhibition in Rome is described. The pieces shown included examples of surface decoration by wheel cutting, enameling, and diamond point; stained-glass windows from Venice and Florence; and revivals of the 18th-century style of cut mirrors and the still older *fondi d'oro* technique at Lecce and Faenza. Mosaic was well represented; the principal teaching centers are Venice and Ravenna, with other centers at Tunis, Parma, and Modena. It is recommended that more attention be paid to the subject of glass decoration in art schools. Mosaics from Venice, Ravenna, and Tunis and cut glass from Venice are illustrated.

Iranian art in the Metropolitan Museum. M. S. DIMAND. *Bull. Metropolitan Mus. Art*, 35 [5] 110–16 (1940).—The collection of prehistoric Iranian (Persian) pottery dating back to 3000 B.C. and even earlier is from Nihavand, Teppeh Hissar, near Damghan, and Teppeh Siyalk, near Kashan, and was presented by the Teheran Museum. In Susa, sculpture was often combined with reliefs made of brick enameled in various colors, an art borrowed from Babylon and developed by Iranian artists in their own way. Under the Seljuks the ceramic art of Iran reached unparalleled heights. Many older techniques were perfected in the 12th and 13th centuries. Lusterware was centered in two cities, Rayy and Kashan, where elaborate ornament used for the decoration of walls and prayer niches and also of vessels was developed. One masterpiece of the Iranian potter's art is a glazed jug with openwork decoration, a technique peculiar to Iran. Some of the ornament and details are painted black and cobalt blue, the whole being covered with a turquoise blue glaze. The date of the jug is A.D. 1215–16. A.A.A.

Pottery-making course at Blue Ridge. ANON. *Bull. Amer. Ceram. Soc.*, 19 [9] 354–55 (1940).

Sudeten art and service glass. A. DORN. *Glashütte*, 70 [20] 253–54 (1940); see "State . . .," *Ceram. Abs.*, 19 [10] 234 (1940). M.V.C.

Sung vase. ALAN PRIEST. *Bull. Metropolitan Mus. Art*, 35 [4] 82–84 (1940).—The museum has recently acquired a rare vase of Chien ware, from the Sung dynasty. Chien ware takes its name from the province of Fukien (Fu-chien) and the cities Chien-an and Chien-yang where it was first

made. The best known examples of the Chien ware are the beautiful tea-tasting bowls, called temmoku ware by the Japanese and widely copied by them. The glazes are thick and come in a variety of silvery blacks and browns, some of which are known as "hare's fur," "oil spots," and "partridge patterns." The Chinese believed that tea looked better when served in black cups and that thick glazes helped to retain the heat. Chien-an was a famous tea-growing center during the Sung dynasty, and these bowls were in great demand for tea-tasting parties. Most of the early black and tan glazes are designated as Chien ware. The newly acquired piece belongs to a group of Chien ware called by the British, "Honan Temmoku." It is made of buff stoneware and has a brownish copper glaze mixed with black on the neck and shoulder; a great heart-shaped blob of lustrous black runs from the shoulder to the foot on one side. The shape is very handsome; one similar to it in the Eumorfopolous collection is described as having a wide ovoid body flattened at the shoulder, a tall slender neck, a flaring mouth, and a bell-shaped foot. Besides these two pieces only one other is known (in the H. J. Oppenheim collection in London). Illustrated. A.A.A.

Two Greek terra cottas. CHRISTINE ALEXANDER. *Bull. Metropolitan Mus. Art*, **35** [5] 107–108 (1940).—Two Greek terra cottas are shown in the Room of Recent Accessions. One is an archaic Greek terra-cotta antefix, one of the finest examples of its kind from the temples of Magna Graecia. Although painted in tempera and long exposed to the weather, it has kept much of its color and is relatively well preserved. On the front panel is a mask of the Gorgon Medusa in relief, with colors applied over a white engobe. The type belongs to the late archaic period (the end of the 6th or the early 5th century B.C.). The other example is a terra-cotta goddess of the Boeotian type. Both pieces are of exceptional quality. Illustrated. A.A.A.

Vienna porcelain. C. LOUISE AVERY. *Bull. Metropolitan Mus. Art*, **35** [8] 161–63 (1940).—Although much care was taken to protect the secrets of the Meissen porcelain factory, Christoph Conrad Hunger, who had been employed there, took his knowledge and skill to a factory established in Vienna in 1718 by a Dutchman, Claude du Paquier. In 1744 the factory was bought by the Empress Maria Theresa and became a serious competitor of Meissen. Nine pieces of this 18th-century Vienna porcelain have recently been purchased for the Museum's collection. Six of them date from about 1725–1740 and illustrate some of the styles for which the factory is renowned, when it was privately owned and in its experimental period. A covered cup and stand dated about 1725–1730 are illustrated. A.A.A.

West Virginia University extension. ANON. *Bull. Amer. Ceram. Soc.*, **19** [9] 358–59 (1940).

PATENTS

Designs for:

Bowl. CHARLES SAWYER (Libbey Glass Co.). U. S. 122,173, Aug. 27, 1940 (Jan. 26, 1940).

Glass tumbler. A. J. DREITZER (Pitman-Dreitzer & Co., Inc.). U. S. 122,393, Sept. 10, 1940 (June 6, 1940).

Goblet. A. J. CUNNINGHAM. U. S. 122,389, Sept. 10, 1940 (May 15, 1940).

Hollow glass building block. R. C. KENDALL (Owens-Illinois Glass Co.). U. S. 122,269, Sept. 3, 1940 (July 18, 1940).

Jar. FRASIER SMITH (Hazel-Atlas Glass Co.). U. S. 122,472, Sept. 10, 1940 (June 8, 1940).

Milk bottle. R. W. NIVER (Thatcher Mfg. Co.). U. S. 122,058, Aug. 20, 1940 (Jan. 5, 1940).

Stove. J. C. ROGERS (Crown Stove Works). U. S. 122,002 and 122,003, Aug. 20, 1940 (June 17, 1940). U. S. 122,032, Aug. 20, 1940 (Jan. 11, 1940).

Toy clay modeler. M. S. LANDOW (Pfaltzgraff Pottery Co.). U. S. 2,213,784, Sept. 3, 1940 (Feb. 24, 1939).—A portable toy modeling apparatus comprises a base, a post mounted on the base having a vertically extending socket the opening of which faces upwardly, and a rotatable chuck for receiving removably the molds for holding the clay to be modeled, the chuck having a depending shaft removably seated in the socket.

Cements

Factors affecting plaster mold life. M. C. DAILEY AND B. NIES. *Bull. Amer. Ceram. Soc.*, **19** [9] 323–29 (1940).

More efficient kiln firing. ANON. *Rock Products*, **43** [8] 43–45 (1940).—Direct-firing coal mills installed on the cement kilns of the Nazareth Cement Co., Nazareth, Pa., are described. Greater combustion economy, higher kiln capacity, and a much more desirable and uniform clinker are obtained. Illustrated. J.J.H.

Solubilization of alkali in natural aluminosilicates. G. A. BLANC AND F. JOURDAN. *Atti X° congr. intern. chim., 1938*, **4**, 7; *Brit. Chem. & Phys. Abs.–B*, **59** [7] 524 (1940).—Alkali metal, especially K, is liberated under definite pressure and temperature conditions by dissociation of the silicate in the presence of CaO and the absence of H_2O in liquid phase, i.e., the reaction occurs in solid phase and in the presence of a gaseous phase.

System calcium oxide–silica–water at 30°C. Association of silicate ion in dilute alkaline solution. PAUL S. ROLLER AND GUY ERVIN, JR. *Jour. Amer. Chem. Soc.*, **62** [3] 461–71 (1940).—Knowledge of the compounds of hydrated calcium silicate and their equilibria is important in cement technology and in the use of siliceous minerals in cement. Hydrated calcium silicates are gelatinous. The effects to be expected from this in a phase-rule study are discussed briefly. Measurements were made of the ratio of CaO to SiO_2 in the solid phase and of the concentrations of CaO and SiO_2 in solution at 30.2°C. Equilibrium and reversibility were tested for. Four phase ranges were distinguished; in two of these the concentrations were invariant. Adsorption of CaO by the solid phases occurred throughout. The compositions of the hydrated compounds, deduced from considerations of adsorption isotherm and solubility product constant, were (*a*) $CaO \cdot SiO_2$ (CaH_2SiO_4), (*b*) $3CaO \cdot 4SiO_2$ ($Ca_3(HSi_2O_6)_2$), and (*c*) $CaO \cdot 2SiO_2$ (indifferently either $CaH_2Si_2O_6$ or $Ca(HSiO_3)_2$). The invariant concentrations were, for the mixture of *a* and *b*, 3.09 millimoles CaO per liter and 0.090 millimole SiO_2 per liter and, for the mixture of *b* and *c*, 0.900 millimole CaO per liter and 0.931 millimole SiO_2 per liter. The assumed exclusive presence of the simple ions SiO_3^{--} and $HSiO_3^-$ (in the more rational and preferred orthosilicate terminology, $H_2SiO_4^-$ and $H_2SiO_4^{--}$) was inconsistent with the existence of the only alternatives of $Ca(H_2SiO_4)_2$ or any reasonable double compounds of the latter with CaH_2SiO_4. It was necessary to assume, therefore, that association took place in the dilute alkaline solutions. The postulate of two sets of silicate ions, based on an association equilibrium between $H_2SiO_4^-$ and $H_2Si_2O_5^{--}$, led to reasonable and concordant results. The association constant, solubility product constants, and one of the ionization constants were calculated to a known precision. A high tendency toward association is evidenced. F.G.H.

PATENTS

Cement manufacture. C. H. BREERWOOD (Separation Process Co.). U. S. 2,214,715, Sept. 10, 1940 (June 2, 1939). U. S. 2,214,716 and U. S. 2,214,717, Sept. 10, 1940 (June 28, 1939).

Producing cement from barium charge. WALDEMAR JENSEN AND FRITZ ENSSLIN (Unterharzer Berg- und Hüttenwerke). Ger. 671,037, Jan. 12, 1939 (Feb. 2, 1937); VI/80*b*. 3.01.—In the formation of cement from

a barium charge, the CaO content is replaced, up to 75%, by BaO. The finished product has a BaO content of 35 to 60%. D.A.B.

Producing cement from barium sulfate charge. BERGINSPEKTION RÜDERSDORF, ZWEIGNIEDERLASSUNG DER PREUSS. BERGWERKS- UND HÜTTEN-A.-G. Ger. 689,269, Feb. 29, 1940 (May 25, 1937); VI/80*b*. 3.01. Addition to Ger. 671,037 (see preceding patent).—Iron compounds, such as Fe_2O_3, are employed for the treatment of charges containing barium sulfate in place of alumina. D.A.B.

Enamel

Cupola control. H. P. HUGHES. *Enamelist*, **17** [11] 9–11, 42–60 (1940).—The cupola is still the most widely used, the most economical, and the speediest unit for the production of cast iron. Ideas and experiences in cupola practice are discussed under the following headings: preparing the cupola, charging, air supply, blast pressure, tuyère ratio, air volume, combustion, fuel consumption, control of pig iron and scrap, limestone, sulfur, silicon, and phosphorus. Illustrated. L.E.T.

De-enameling of vitreous enamel steel and sheet iron. N. L. EVANS. *Enamelist*, **17** [10] 18–29 (1940).—Methods of de-enameling steel and sheet iron and the problems encountered are discussed. Factors influencing the choice of a de-enameling process are summarized. Where speed is not important and there is a steady flow of flat or nearly flat parts, the caustic solution method with its comparatively low capital cost has proved satisfactory. The consumption of caustic soda is said to be about $^1/_2$ lb. per sq. ft. of porcelain enamel treated. For speedy operation and parts of a bulky nature, the molten caustic method has an obvious advantage. The consumption of caustic soda by this method is two or three times as great as by the solution method. Molten caustic is also desirable when acid-resistant enamel is to be removed. L.E.T.

Determination of thickness of acid-resistance portion of vitreous enamel coatings. WILLIAM N. HARRISON AND LEO SHARTSIS. *Jour. Research Nat. Bur. Standards*, **25** [1] 71–75 (1940); RP 1315. Price 5¢.—An oblique section of the enamel approximately 1 cm. wide is exposed by grinding. The boundaries of this section are permanently marked, and the oblique section is given a fire polish by refiring. The surface is then exposed to acid, after which it is coated with colored wax. When the surface is rubbed, this wax is removed from the acid-resisting enamel, which retains its gloss in the acid, but is retained by the etched portion of the oblique section. The fraction of the oblique section which is occupied by the acid-resisting enamel is then determined, and this fraction is multiplied by the total thickness of enamel as measured by a magnetic gauge. The product gives the thickness of the layer of acid-resisting enamel. R.A.H.

Discussion of "Relation of defects in enamel coatings to hydrogen in steel." W. A. WEYL ET AL. *Jour. Amer. Ceram. Soc.*, **23** [10] 291–96 (1940); see *ibid.*, [7] 187–221. **Reply.** C. E. SIMS AND C. A. ZAPFFE. *Ibid.*, [10] 296–300.

Enameling furnace equipped with refractory radiant tubes. W. F. ROSS. *Ind. Heating*, **7** [9] 825–29, 837 (1940).—Major factors which must be considered in the successful application of vitreous enamel to steel are (1) frit or enamel, (2) kind and surface condition of the steel, and (3) the means by which the radiant heat is applied for fusion. The first two factors are controlled by the quality of the material, but the third depends entirely on the furnace equipment for vitreous enameling. R. gives the requirements for the equipment and describes recent developments in which a muffle effect within the fusion chamber is provided by firing beneath the flat tongue-and-groove type silicon carbide working hearth and exhausting the combustion products through vertical silicon carbide radiant tubes spaced along each side of the chamber. The firing chamber is arranged under the working hearth and contains the gas burners. Temperature control is arranged for two zones, controlling the gas and air supply to each zone according to their thermal requirements. Refractory radiant-heating tubes provide full utilization of the bottom and side-wall areas as sources of radiant heat; in some cases the radiating area is more than twice that of a conventional arch muffle-type enameling furnace. Recuperators for air preheating can be arranged for such a furnace. Details of the construction and operation of a furnace are given. M.H.

Glass-lined equipment. P. S. BARNES. *Ind. Eng. Chem.*, **32** [9] 1158–59 (1940).—The development of glass-lined steel chemical process equipment is briefly described. Illustrated. F.G.H.

Luminous porcelain enamel for signs and other uses. G. D. SKINNER. *Enamelist*, **17** [11] 6–8 (1940).—A successful method of applying certain types of fluorescent materials to vitreous porcelain enamel has been developed. Several methods of applying fluorescent powders and glazes and firing them to approximately 840° to 860°C. are described. Luminous enamels are attractive for advertising signs and store fronts and have recently found special application in Europe as street signs, obstruction signs, etc., during nightly black-outs. L.E.T.

Masterpieces of enameling. AMBROSE LANSING. *Bull. Metropolitan Mus. Art*, **35** [5] 99–103 (1940).—Enamels from the Museum's collections have been shown together for the first time. Enamels and glass are significant items in our heritage from the Middle Ages. Their colors have retained their original freshness and give a vivid glimpse of the splendor of that period. This exhibition of masterpieces shows the many kinds of enamels and the special techniques used. There are examples of cloisonné, champlevé, and painted enamels, and that called *basse-taille* which was done with transparent glaze on designs cut in low relief on silver, the varying thicknesses of the enamel resulting in lighter and deeper shades of color, thus enhancing the modeling. Illustrated. A.A.A.

Molybdenum in enamels: I, Adherence produced with molybdenum compounds. KARL KAUTZ. *Jour. Amer. Ceram. Soc.*, **23** [10] 283–87 (1940).

Solubility of zirconium oxide opacifier in enamel glasses. A. I. ANDREWS AND R. W. GATES. *Jour. Amer. Ceram. Soc.*, **23** [10] 288–90 (1940).

SEPARATE PUBLICATION

Ball Mill Wet Grinding of Porcelain Enamels. TECHNICAL RESEARCH SECTION, PORCELAIN ENAMEL INSTITUTE. Porcelain Enamel Institute, Inc., Chicago, 1939. 13 pp., 1 table, 4 figs. Price 25¢.—A survey of thirty enamel plants provides data on the size of production mills, kind of lining, size of ball charges, types of pebbles, water content used, r.p.m. of mills, milling time, etc. The booklet is divided into three parts: (*a*) recommended practice for ball-mill grinding, (*b*) practical relations in ball-mill operation, and (*c*) mechanics of mill and ball action. F.J.Z.

PATENTS

Enamel protective coating on metallic and ceramic articles. MAX PASCHKE. Ger. 686,557, Dec. 14, 1939 (April 19, 1938); VI/48*c*. 2.01.—Refining slag, especially so-called desulfurized slag, containing alkalis and silicic acid obtained by the oxidation of silicon is employed either alone or with the addition of suitable enamel formers as the enamel. D.A.B.

Enameled wire. N. V. POPE'S METAALDRAADLAMPENFABRIEK. Brit. 524,166, Aug. 14, 1940 (Jan. 25, 1938).

Enameling articles of different dimensions. CARL THIEL. Ger. 684,197, Nov. 2, 1939 (Feb. 25, 1937); VI/48*c*. 7. Addition to Ger. 663,940 (*Ceram. Abs.*, **18** [2] 44 (1939)).—In enameling articles of different dimensions the working process is carried out in several horizontal rows running parallel to each other. The workpieces pass at intervals through one or more vertically arranged driers with special moving conveyers. While passing through the driers, the workpieces are gradually heated up

by the same air current, if desired, are dried, and then cooled off again, until they pass in a horizontal direction over the firing grates which are oblique to the conveyer paths. The workpieces corresponding to each other are loaded on the conveyers and pass through the drying and preheating chambers of the enamel firing furnace where those of different style and wall strength are gradually heated with special heaters using city gas, steam, etc., so that the thick pieces, as far as possible, are preheated to approximately the sintering temperature in the hottest section of the furnace, are then brought to the firing chamber in which they are finally fired, and are removed. D.A.B.

Indirect lighting fitting. G. D. SKINNER (Benjamin Electric Mfg. Co.). U. S. 2,215,234, Sept. 17, 1940 (Nov. 21, 1939).

Glass

Atomic consideration of immiscibility in glass systems. B. E. WARREN AND A. G. PINCUS. *Jour. Amer. Ceram. Soc.*, **23** [10] 301–304 (1940).

Bending of glass under long-continued stress. RAYLEIGH. *Nature*, **145** [3662] 29 (1940).—R. supported a piece of optically flat crown glass (3.5 cm. long, 1.5 cm. broad, and 0.3 cm. thick) on wood at the extreme ends and loaded the middle with 6 kgm. applied by means of a wooden chisel edge which carried a weight moving in guides above. After 1 year and 8 months under this load the glass was taken out and tested on an optical flat by means of interference fringes. It was bent, the sagitta of the arc amounting to 2.5 bands or 1.25 waves, i.e., about 6×10^{-5} cm. J.L.G.

Care in unloading boxes or frames for holding panes of glass on auto trucks. ANON. *Sprechsaal*, **73** [21] 189 (1940).—Several cases of breakage of sheet glass during unloading were attributed to the supports and chains used on the auto trucks. The trucks were not of the type specially constructed for transporting sheet glass. M.V.C.

Combination furnace for glass manufacture. M. G. STEPANENKO, L. K. KOVALEV, AND B. M. POLIK. *Keram. & Steklo*, **14** [3] 31–39 (1938).—A detailed description of an experimental glass furnace is given. Basically, it is a combination of a shaft and a tank furnace; the beginning of melting, i.e., the melting and formation of glass, takes place in the shaft furnace, while the degasification and homogenization of the glass occur in the tank furnace. M.V.C.

Conductivity of thin films of thallium on a Pyrex brand glass surface. J. R. BRISTOW. *Proc. Phys. Soc.* [London], **51** [2] 349–54 (1939).—Thin films of thallium were prepared by condensation of the metal on a cooled Pyrex brand glass surface at a pressure of 10^{-7} mm. of mercury or less. At a thickness of more than 40 a.u. the films show a resistivity only about three times greater than that of the bulk metal. The results tend to substantiate the views of Appleyard and Lovell ("Electrical . . .," *Ceram. Abs.*, **17** [11] 350 (1938)) that evaporated films do not differ radically in structure from the bulk metal, at least after the first atomic layers. The thallium films differ in an important respect from both the alkali films and from mercury. Unlike the alkali-metal films, they show no conductivity until the film is about five atomic layers in thickness, and, unlike mercury films which show a similar delayed conductivity, they have a finite range of thickness in which resistivity is very high. It seems possible that the material is only semiconducting in this range, possibly owing to distortion of the normal metallic lattice by the atoms of the substrate. Deposition of films in a poor vacuum, between 10^{-7} and 10^{-5} mm. of mercury, has demonstrated the far-reaching effects of occluded gas in the films. This may raise the resistivity at a given thickness by a factor of 10^4 or more and also alter the temperature coefficient from the consistent positive values obtained in a good vacuum to large and variable negative values. 3 diagrams, 1 table. L.E.T.

Glass in architecture. ANON. *Vetro*, **2** [12] 450 (1939); *Jour. Soc. Glass Tech.*, **24** [102] 106A (1940).—The façade of an establishment at Vigevano shows a harmonious alternation of courses of glass blocks with continuous windows, while the interior shows the spacious effect of the resultant light diffusion. Continuous desk tops of glass add to the effect of clarity and order. Globular prismatic lighting fixtures are hung from the ceiling. Illustrated.

Glass in Australian architecture. ANON. *Decoration & Glass*, **5** [6] 10, 18, 28; [7] 10, 30 (1939); *Jour. Soc. Glass Tech.*, **24** [102] 107A (1940).—The buildings described are Wireless House, Sidney; Hotel Mosman, N.S.W.; Qantas Empire Airways, Mascot; Nesca House, Newcastle, N.S.W., and Metro Theatre, Adelaide. Insulux glass brick are used to give light in the tower at Wireless House, on the staircase at Hotel Mosman, and in the vestibule at Qantas Empire Airways. Plate glass is used in single sheets and panels, sometimes treated with gravé, for doors, fanlights, and partitions. Fluted and reeded glass is also used in panels and partitions. Bent glass is used on corner sites, with particular effect in the sunroom of the Hotel Mosman. Black structural glass is decoratively employed for fireplace surrounds, a clock, and table tops. Mirror glass is extensively used as wall decoration at the Metro Theatre, and crystal chandeliers light the foyer. Of special interest are glass mosaics at Wireless House, on the floor of the vestibule and on the street façade. Light fittings used are in the appropriate form of wireless valves. A feature at Nesca House is a screen wall between the theater and the display hall consisting of a large single panel of plate glass treated with gravé.

Glass for engineering and industry. LEON QUIGLEY. *Ind. Eng. Chem.*, **32** [9] 1176–78 (1940).—The ability of the glass industry to meet the requirements of the rearmament program is briefly discussed. Illustrated. F.G.H.

Illumination for the home. ANON. *Sprechsaal*, **73** [8] 64 (1940). M.V.C.

Industrial uses for glass. ANON. *Mill & Factory*, **25** [5] 114 (1939).—Invisible glass, sealed-beam auto lights, special auto glass that breaks with rounded edges, heat-resistant skillets, and fiber glass are cited as industrial uses of glass. D.A.B.

Methods used to reduce surface lines on glass. R. L. SHUTE. *Bull. Amer. Ceram. Soc.*, **19** [9] 329–30 (1940).

New development in pot annealing ovens. OTTO EHINGER. *Sprechsaal*, **73** [9] 72–73 (1940).—Obsolete coal-fired annealing ovens were converted to gas-fired ovens, the muffle form being abandoned in order to increase production. Gas-fired ovens cost less to build than other types, and their thinner walls and good insulation reduce fuel consumption. Unpurified generator gas made from lignite briquette and under regulated pressure (registered on a hydrogas pressure recorder) was used as fuel. The flame is easily controlled, and the gas pipes are so arranged that impurities such as tar water settle in "stand" pipes and can be cleaned out, while the gas pipes remain clean. The pots are placed in the oven when the temperature is between 50° and 90°, and the annealing time need not be over 60 hr. to raise the temperature of the pots to 900°. The life of the pots is 20 to 35 melts. It is also possible to anneal pots with a capacity of 1100 liters in 60 hr., and a curve showing a temperature increase to 850° in 42 hr. is given. Gas-fired ovens of this type can be installed in any glass plant at low cost, and they are as satisfactory as ovens fired with the newest heating methods. See "Annealing . . .," *Ceram. Abs.*, **19** [5] 109 (1940). M.V.C.

Optical glass. GEORGE W. MOREY. *Ind. Eng. Chem.*, **32** [9] 1178 (1940).—Optical-glass manufacture for war requirements is briefly discussed. F.G.H.

Powder method for measurement of chemical durability of glass. F. V. TOOLEY AND C. W. PARMELEE. *Jour. Amer. Ceram. Soc.*, **23** [10] 304–14 (1940).

Safety glass. ANON. *Verre & Silicates Ind.*, **11** [4] 51–52 (1940).—The advantages and disadvantages of (1) sandwich glass, (2) organic glass, and (3) hardened glass are given to enable manufacturers of vehicles to select the most suitable variety. Organic glasses have many advantages because they can be given a variety of shapes and are almost unbreakable; they are not sufficiently hard for windshields, however, and are still expensive. Hardened glass cannot be used for windshields because visibility is greatly impaired if the glass is injured by impact. M.V.C.

Solubilities and separations in glasses. MARC FOËX. *Ann. Chim.*, **11**, 359–452 (1939).—The solubility of the oxides X_2O, XO, X_2O_3, XO_2, and X_2O_5 in borax heated at high temperatures was investigated. The study covers separations taking place with temperature changes and upon solidification; the solubility of oxides in glasses having two constituents; glasses at high temperatures; the effect of pressure, temperature, and nature of the constituents; the composition of glasses; preliminary treatment of glasses; the duration of treatment; glass surfaces; and the effect of gases. 108 references. See *Ceram. Abs.*, **17** [7] 264 (1938). D.A.B.

Tank furnace with circulation for the production of chemical glass. M. A. BEZBORODOV. *Stekolnaya Prom.*, **14** [8–9] 25–27 (1938).—A tank furnace for melting chemical glass is a regenerating furnace with two pairs of burners and with a circulating and transverse movement of the flame. The special characteristic of the tank is its low depth to produce high quality glass. Details are given. M.V.C.

Tempering of borosoda glasses. MARC FOËX. *Bull. Soc. Chim., Mem.*, [5]**6**, 1056–61 (1939).—F. deals with X-ray diffraction spectra and the measurement of the densities of borosoda glass and tempered, annealed, and devitrified glasses. Discussions on the vitreous state are given from previous findings. The probable existence of a marked limit between the vitreous state and the crystallized state is emphasized. See "Effect of annealing . . . ," *Ceram. Abs.*, **18** [6] 151 (1939). D.A.B.

Trends in insulation practice. C. LYNN. *Iron & Steel Engr.*, **16** [8] 40–53 (1939).—The manufacture and uses of mica, glass, oxides, enamels, shellac, and varnish are described. For use as insulation, thick sheets of mica are best built up of thin shells turned 90° with respect to each other, held together by bond, and fired. White mica stands working temperatures up to 500°C., and amber mica, temperatures up to 1000°C. Woven spun-glass insulation without impregnation is stronger and can stand higher temperatures than any competing insulation; it does not take a permanent set below 650°C. Aluminum oxide on aluminum wire may act as a conductor insulation under application of low voltage. The use of chemical coatings or impregnations lowers the operating temperature of glass insulation but raises the breakdown voltage. B.L.

Use of dynamic viscosimeter in the glass-tank furnace. M. S. KAZANSKIĬ. *Stekolnaya Prom.*, **14** [10] 27–29 (1938).—Experiments with a new dynamic viscosimeter developed by K. G. Kumanin are described in detail. M.V.C.

Variation of resistance and power factor of glass condensers with radio frequencies. HAZEL M. FLETCHER. *Phil. Mag.*, **24** [160] 319–24 (1937).—At frequencies of 76 to 8250 kc., resistance shows a slight maxima at 1300 and 1900 kc., and power factor curves have a flat region at the same frequencies. The greater part of the resistance of glass condensers is due to dielectric losses, a portion of which is due to Debye's polar orientation. H.H.S.

Viscosity of coal-ash slags. P. NICHOLLS AND W. T. REID. *Trans. Amer. Soc. Mech. Engrs.*, **62** [2] 141–53 (1940).—A viscometer for measuring the viscosity of coal-ash slag at temperatures up to 2900°F. is described. The investigations show that slags in only a relatively small portion of the field of compositions of coal ash have the melting characteristics of glasses and that, for most compositions, there is a distinct liquidus point. From the limited data available, plots for viscosity are given for 2800°, 2600°, 2400°, and 2200°F., and the liquidus lines for each temperature are shown. The relation between "flow temperature," as determined in earlier investigations on slag-tap furnaces (*Ceram. Abs.*, **14** [10] 263 (1935)), and viscosity and liquidus temperature is derived. When complete trilinear diagrams are available, accurate predictions can be made on the effect of mixing the ashes of two coals or of the addition of the main constituents. Predictions of the relative fusion and clinkering characteristics of coals from the softening temperatures of their ashes may give erroneous comparisons, but the initial and fluid temperatures can be additional guides. Illustrated. F.G.H.

PATENTS

Apparatus for bending sheet glass. O. H. PADDOCK AND A. McK. GREAVES-WALKER (Libbey-Owens-Ford Glass Co.). U. S. 2,213,406, Sept. 3, 1940 (Sept. 29, 1938).

Apparatus for feeding batch to glass furnaces. B. H. WEEKLEY (Libbey-Owens-Ford Glass Co.). U. S. 2,212,358, Aug. 20, 1940 (April 16, 1938).

Apparatus and method for controlling the feeding of glass charges. J. T. WOOD. U. S. 2,215,417, Sept. 17, 1940 (Nov. 25, 1938).

Apparatus for obtaining tempered glass sheets. E. FERLITO. Brit. 524,484, Aug. 21, 1940 (Jan. 31, 1939).

Apparatus and process for cooling glass articles by means of moving jets for the purpose of tempering. GEORGES MONNET (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). Ger. 680,195, Aug. 3, 1939 (Nov. 6, 1937); VI/32*a*. 30.—Glass articles are treated for the purpose of tempering by means of moving jets of gases or liquids which exert a cooling effect on the surface of the article being annealed or tempered. Fixed jets with two or more channels for the coolant are employed whose openings for the escape of the coolant are so close to each other that a uniform jet of coolant is produced. The mass escaping from the individual jets can be varied temporarily in any amount; the shape of the jets and their position are such that the range of action of the jets (uniformly produced) covers the entire article to be treated. D.A.B.

Apparatus for producing hollow glass objects with reinforced base ends. MAX ANDING AND ALBIN HESS (Jakob Dichter). Ger. 688,536, Feb. 8, 1940 (May 29, 1937); VI/32*a*. 27.—An apparatus is described for producing hollow glass articles with reinforced base ends from glass tubes. After the glass mass is heated up for sufficient gathering, the base ends to be reinforced are blown by turning the mass around the longitudinal axis of the glass tube and pushing it against the form surfaces determining the design of the base and the side walls of the tube. The apparatus has a mechanical driving unit for the base form which imparts a relative motion to the base ends while they are being blown up; this motion is opposite to that of the motion of the glass tube. D.A.B.

Apparatus for tempering glass. O. H. PADDOCK (Libbey-Owens-Ford Glass Co.). U. S. 2,213,405, Sept. 3, 1940 (Nov. 18, 1937).

Apparatus for use in the bedding of glass sheets preparatory to surfacing. JOHN MORAN AND M. N. KEPLER (Libbey-Owens-Ford Glass Co. U. S. 2,212,351, Aug. 20, 1940 (March 11, 1938).

Applying a metallic covering to quartz glass or glasses similar to quartz. HANS PULFRICH, RICHARD WAGNER, AND PETER KNIEPEN (Patent-Treuhand-Ges. für elektrische Glühlampen m.b.H.). Ger. 680,371, Aug. 3, 1939 (Nov. 24, 1937); VI/32*b*. 10.—A method is given for applying a metallic, electricity-conducting, solderable coating to quartz glass or glasses resembling quartz. A metallic covering having a higher melting point than the quartz glass being used is applied to the article in the form of a fine granular suspension or paste and is treated by heating it to a temperature above the melting point of the quartz surface but below the fusing temperature of the metal. The entire heating process of the metal coating, from the beginning of the application of heat to the end of the cooling period, takes about 1 to 2 min. D.A.B.

Cathode-ray tubes and like electric discharge devices having ceramic bases. GENERAL ELECTRIC CO., LTD.,

J. Richards, and G. W. Warren. Brit. 524,826, Aug. 28, 1940 (Feb. 8, 1939).

Coating glass, etc. Neonelectric Co., Ltd., and O. P. Scarff. Brit. 524,427, Aug. 21, 1940 (Jan. 31, 1939).

Coating glass fabric. C. A. Alt (E. I. du Pont de Nemours & Co.). U. S. 2,215,061, Sept. 17, 1940 (Feb. 25, 1937).—The process comprises coating a woven glass fabric with a composition consisting of cellulose nitrate 14.0, castor oil 18.6, pigment 23.4, ethyl acetate 17.6, and ethyl alcohol 26.4% and thereafter drying.

Coloring quartz glass objects. Franz Skaupy and Gustav Weissenberg. Ger. 689,872, March 21, 1940 (July 26, 1937); VI/32*b*. 2.—The low oxides of metals whose most stable step of oxidation forms a white, slightly colored, acid anhydride are employed as the coloring material. D.A.B.

Division, corner, and reverse bar. C. D. Lowry (Libbey-Owens-Ford Glass Co.). U. S. 2,213,402, Sept. 3, 1940 (Aug. 23, 1937).

Electrically heated mouthpiece on a furnace for producing threads or filaments from glass or materials plastic when heated. Adolph Dietzel (Kaiser Wilhelm-Institut für Silikatforschung). Ger. 684,081, Nov. 2, 1939 (Dec. 17, 1937); VI/32*a*. 25.—The outlets of the electrically heated mouthpiece have an oblong or elliptical cross section, and their longitudinal direction is parallel to the general direction of the heated stream passing through the mouthpiece. D.A.B.

Fluorescent glass. H. P. Hood (Corning Glass Works). U. S. 2,215,040, Sept. 17, 1940 (Feb. 8, 1939).—A glass which contains thallous oxide which will fluoresce substantially white when irradiated at a wave length of about 3650 a.u. and which is free from second group sulfides.

Forming sealed hollow articles of glass. H. H. Blau (Corning Glass Works). U. S. 2,215,027, Sept. 17, 1940 (Sept. 12, 1939).

Frost-resistant glass. Fred Cornetto (M. M. Sullivan). U. S. 2,215,209, Sept. 17, 1940 (Aug. 26, 1939).—A method of making a frost-resistant glass comprises mixing a glassforming batch with alcohol and water, heating the mixture to dryness, melting the thus-treated batch, and forming glass articles from the melt.

Glass-inspection apparatus. E. L. Walters (Libbey-Owens-Ford Glass Co.). U. S. 2,213,422, Sept. 3, 1940 (Sept. 22, 1937).

Glass mold. W. McK. Greed (J. A. Weirich). U. S. 2,212,984, Aug. 27, 1940 (April 17, 1937).

Heating and reshaping glass articles. J. C. Hostetter (Corning Glass Works). U. S. 2,215,041, Sept. 17, 1940 (Dec. 7, 1938).

Lehr drive for sheet-glass machines. J. H. Redshaw (Pittsburgh Plate Glass Co.). U. S. 2,215,231, Sept. 17, 1940 (Oct. 9, 1937).

Lens-grinding machine. K. C. Burroughs (Bausch & Lomb Optical Co.). U. S. 2,214,361, Sept. 10, 1940 (April 10, 1935).

Lens manufacture. J. D. Gamble. U. S. 2,213,958, Sept. 10, 1940 (May 27, 1937).—A machine for reducing a glass blank to the form of a bifocal lens.

Machine for grinding or polishing lenses. Douglas Taylor. U. S. 2,214,977, Sept. 17, 1940 (March 25, 1940).

Machine for sealing-in and molding lamp bulbs. M. E. McGowan (Westinghouse Electric & Mfg. Co.). U. S. 2,212,842, Aug. 27, 1940 (Dec. 21, 1935).

Making glass-coated articles. J. T. Littleton (Corning Glass Works). U. S. 2,212,162, Aug. 20, 1940 (Jan. 6, 1938).—The method of manufacture of a screen suitable for filtering acids and similar corrosive materials includes submerging a metallic screen into a bath of molten glass, withdrawing the coated screen therefrom, draining surplus glass from the screen in a heated chamber, and opening up any mesh bridged by a film of glass by playing a flame thereon.

Making mirrors. William Peacock (Peacock Laboratories, Inc.). U. S. 2,214,476, Sept. 10, 1940 (Oct. 18, 1938).

Manufacture of ceramic products. N. S. Garbisch. U. S. 2,215,215, Sept. 17, 1940 (Jan. 12, 1938).—A process of manufacturing translucent ceramic bodies comprises grinding glass by means of sand of the purity of glass-batch sand as an abrasive, thereby providing a mixture of pulverulent silica and glass of a particle size such that substantially all of it will pass through a screen of 325 mesh, washing the pulverulent material with dilute mineral acid, mixing it with clay to form a plastic coherent mass in which the clay constitutes about 50% of the whole, shaping the masses into bodies of desired form, and firing them until the bodies are vitrified to a hard translucent state.

Manufacture of glass-like quartz. A. F. Burgess (Vereinigte Glühlampen und Elektrizitäts Akt.-Ges.). Brit. 524,442, Aug. 21, 1940 (Dec. 29, 1938).

Manufacture of glass phials, bottles, etc. Johnson & Jorgensen Flint Glass, Ltd., and E. Ashford. Brit. 524,927, Aug. 28, 1940 (Jan. 9, 1939).

Manufacture of laminated glass. F. L. Bishop and C. S. Shoemaker (American Window Glass Co.). U. S. 2,214,158, Sept. 10, 1940 (Dec. 1, 1936).

Manufacture of multiple glass sheet glazing units. J. J. Hopfield (Libbey-Owens-Ford Glass Co.). U. S. 2,213,395, Sept. 3, 1940 (July 14, 1937).—In the fabrication of a multiple glass sheet glazing unit including a plurality of sheets of glass and separator means arranged between the glass sheets around the edges thereof and bonded thereto to provide an air space therebetween, the process consists in first providing an opening in the separator means communicating with the air space, placing the unit in a chamber, creating a vacuum within the chamber to exhaust the air from within the unit, heating the unit in vacuum, and finally closing the opening.

Manufacture of threads of glass, etc. Soc. Anon. Vetreria Italiana Balzaretti Modigliani. Brit. 524,528, Aug. 21, 1940 (March 22, 1938).

Means for opening and closing the molds of a machine for forming glassware. T. F. Pearson (Crown Cork & Seal Co., Inc.). U. S. 2,212,699, Aug. 27, 1940 (Sept. 15, 1936).

Method and apparatus for melting and fining glass. Games Slayter (Owens-Corning Fiberglas Corp.). U. S. 2,212,528, Aug. 27, 1940 (Dec. 28, 1935).

Method and apparatus for the production of fibers from molten glass, etc. Piero Modigliani (Owens-Corning Fiberglas Corp.). U. S. 2,212,448, Aug. 20, 1940 (Feb. 12, 1937).

Method and machine for sealing vitreous vessels. D. S. Gustin (Westinghouse Electric & Mfg. Co.). U. S. 2,215,100, Sept. 17, 1940 (May 22, 1937).

Mortar-bonded glass structure. R. R. McGregor and E. L. Warrick (Corning Glass Works). U. S. 2,215,048, Sept. 17, 1940 (April 18, 1939).

Multiple glass sheet glazing unit. C. D. Haven (Libbey-Owens-Ford Glass Co.). U. S. 2,213,468, Sept. 3, 1940 (Dec. 26, 1935).

Nondrip milk bottle. H. L. White and J. A. Keenan (General Ice Cream Corp.). U. S. 2,214,004, Sept. 10, 1940 (Jan. 27, 1940).

Ophthalmic lens. M. R. Scott (Bausch & Lomb Optical Co.). U. S. 2,214,385, Sept. 10, 1940 (Oct. 9, 1935; renewed April 12, 1940).

Porous material manufacture. W. O. Lytle (Pittsburgh Plate Glass Co.). U. S. 2,215,223, Sept. 17, 1940 (Dec. 30, 1937).—A process of preparing cellular glass comprises filling a vertical column with molten glass, the molten glass at the bottom of the column being under substantial hydrostatic pressure resulting from the glass above, introducing gas into the portion of molten glass under pressure, flowing the gasified material under pressure into a zone of relatively reduced pressure to allow the gases to expand and form a highly cellulated coherent body, and cooling the body.

Process and apparatus for bending glass sheets. J. G. Oliver (Pittsburgh Plate Glass Co.). U. S. 2,215,228, Sept. 17, 1940 (April 21, 1937).

Process and apparatus for making base assemblies for sealed glass envelopes. Corning Glass Works. Brit. 524,127, Aug. 14, 1940 (Feb. 28, 1938).

Process and apparatus for working glass bodies. Corning Glass Works. Brit. 524,126, Aug. 14, 1940 (Feb. 19, 1938).

Producing a durable and strongly adhering silver coating on the upper surfaces of glass. Fritz Neumann. Ger. 684,082, Nov. 2, 1939 (April 13, 1938); VI/32*b*. 10.—A durable, adhering silver coating on the upper surfaces of glass is produced by pouring a mixture of alcohol, lead acetate, and butyl acetate (or amyl acetate) with a small percentage of so-called silver glance over the glass surface. The excess mixture is drained off, and this process is repeated with a solution of celluloid or nitrocellulose in butyl acetate (or amyl acetate); the glass surface thus treated is subjected to a temperature of about 200°C. D.A.B.

Producing fine sieves, filters, spinneret plates, etc., from plastic or molten glass. Heinrich Severin. Ger. 685,105, Nov. 16, 1939 (Sept. 30, 1937); VI/32*a*. 24.04.—Openings are produced in the plastic or molten glass mass by pressing or stamping. The plastic mass, before becoming hard, is subjected to a pressure which is axial to the openings, so that they may be diminished to the desired small diameter. D.A.B.

Producing glass building blocks consisting of a hollow object and a cover. Games Slayter (A.-G. der Gerresheimer Glashüttenwerke vorm. Ferd. Heye). Ger. 684,257, Nov. 2, 1939 (Sept. 30, 1937); VI/32*a*. 24.04.—Hollow glass building blocks are constructed from a hollow object and a cover which are joined together with an organic binding material. The hollow object is placed on the edge of the receptacle containing the binding agent with its opening facing downward, and an immobile organ applies the binding agent mechanically to the desired spot on the hollow object; the object is then placed over a jet giving off dry hot air for the purpose of heating the interior of the hollow object, and the cover plate is pushed over the spot and is pressed from below against the hollow object to bring about a complete union. D.A.B.

Producing a glass mixture containing lime. Howard Eells, Jr., and Harvey Barrett (Non-Metallic Minerals, Inc.). Ger. 689,628, March 14, 1940 (March 2, 1937); VI/32*a*. 1.—The lime is introduced into the glass mixture in the form of a sintered product which is obtained by sintering limestone with small amounts of material containing alumina (3 to 8%). D.A.B.

Producing glass tube connections on hollow glass objects. Karl Eichhorn (Vereinigte Lausitzer Glaswerke A.-G.). Ger. 686,722, Dec. 21, 1939 (March 8, 1938); VI/32*a*. 8.—In a method for producing glass tube connections on hollow glass objects, the connection is produced on the heated glass object from a plastic glass mass by means of a form and is then fused with the hollow glass object. The connection is formed by pressing by employing a die. The separating wall remaining inside the pressed connection is removed by means of a rammer. D.A.B.

Producing hollow glass objects with reinforced bases from glass tubes. Jakob Dichter. Ger. 685,193, Nov. 16, 1939 (Nov. 23, 1934); VI/32*a*. 27.—Hollow glass objects with reinforced bases are produced by forming the bases of the workpieces (preformed and made in sets of two by drawing out a glass tube sufficient for two hollow glass objects) and using an interposed plate and an independent side wall while the glass is in the heated stage. The glass tubes are drawn out and sealed off, the ends are blown up so that a cylindrical roller can be momentarily applied, and the units are fashioned into a hollow glass object with a reinforced base and walling by applying a crescent-shaped base plate which only partly touches the base of the glass tube and is mobile in the axis direction in the working position. D.A.B.

Producing ornamental glass tile. A. D. Nash (Pittsburgh Plate Glass Co.). U. S. 2,215,227, Sept. 17, 1940 (June 15, 1938).

Producing tight unions between glass and ceramic articles. Porzellanfabrik Kahla. Ger. 688,373, Feb. 1, 1940 (Nov. 23, 1932); VI/80*b*. 24.01.—A method for the union of ceramic materials with glasses is given. Pure silicates containing magnesium are used for the production of the ceramic article, e.g., Calit, whose thermal coefficient of expansion is above that of the glasses employed. D.A.B.

Production of glazed fabrics. Tootal Broadhurst Lee Co., Ltd., H. Corteen, R. P. Foulds, and F. C. Wood. Brit. 523,731, July 31, 1940 (Jan. 13, 1939).

Production of safety glass. Chemische Forschungsges. m. b. H. Ger. 679,898, July 27, 1939 (Nov. 27, 1934); IV*c*/39*b*. 27.—The binding agent is applied between the glass sheets to be joined together in the form of cast or formed cylindrical-, lens-, or globular-shaped pieces of small dimensions. Only a small part of the glass to be pressed is touched by the binding agent. D.A.B.

Sealing glass with ceramic material. C. Lorenz Akt.-Ges. Brit. 524,339, Aug. 14, 1940 (Jan. 27, 1938).

Treating borosilicate glasses. H. P. Hood and M. E. Nordberg (Corning Glass Works). U. S. 2,215,039, Sept. 17, 1940 (March 19, 1934; Sept. 20, 1934).—The process comprises melting a glass containing approximately 75 silica, 20 boric oxide, and 5% soda, fabricating it into a fixed shape, removing the surface of the fabricated glass, heat-treating the fabricated glass at between 500° and 750°C. until it separates into two phases, leaching the heat-treated glass in an acid bath containing salts in solution to dissolve out one of the phases, washing the remaining phase, and heating the washed phase to a vitrifying temperature without destroying its shape.

Treating mineral fibrous substances, such as glass wool, slag wool, etc. Clemens Hannen. U. S. 2,215,150, Sept. 17, 1940 (Dec. 16, 1937).—A process for the treatment of siliceous fibers comprises forming fibers from molten material and, while the fibers are still plastic, coating the surface thereof with a dust composed of a finely pulverized material selected from the following group consisting of glass, sand, quartz sand, asbestos, quicklime, limestone, fluorspar, chalk, and pumice stone to render them more suitable for spinning and weaving.

Wall constructed of hollow glass building blocks. J. E. Bauer (A.-G. der Gerresheimer Glashüttenwerke vorm. Ferd. Heye). Ger. 684,379, Nov. 9, 1939 (Oct. 20, 1937); V/37*a*. 5.—A hollow glass block possesses a coating of titanium oxide enamel or a similarly acting enamel and is sprinkled with grit, sand, etc., on the sides usually coming in contact with the mortar. D.A.B.

Workpiece holder for glass-grinding machine. E. F. Preissler and Arno Nestler. Ger. 683,997, Oct. 26, 1939 (June 29, 1938); XII/67*a*. 17.—A glass-grinding machine has a workpiece holder for conical hollow objects which is operated by means of a suction. D.A.B.

Structural Clay Products

Experiments on the technical production of lime-ash brick. L. A. Kislyakov. *Stroitel. Materialy*, **1936**, No. 12, pp. 22–24; *Chem. Zentr.*, **1938, II**, 920; *Chem. Abs.*, **34**, 4534 (1940).—Good results were obtained in the production of brick from slag-ash wastes from technical furnaces when 8 to 10% of lime was added and the pressed mass contained 12 to 15% moisture. The brick so produced scarcely differed from ordinary silicate brick in its value as a building material.

PATENTS

Brick stack grab. R. A. Fontaine. U. S. 2,213,629, Sept. 3, 1940 (May 12, 1937).

Building structure. C. S. Brown. U. S. 2,214,657, Sept. 10, 1940 (March 16, 1939).—A building structure includes brick arranged in tiers with a brick of each tier abutting against each other and lying directly on the next underlying tier, the brick of each tier including alternate stretcher and header brick, the confronting faces of the

header and stretcher brick being complementally beveled from the front faces of the stretcher brick to the back faces thereof and so arranged that the header brick fit between the stretcher brick keystone fashion.

Damp-proof courses for walls, etc. A. J. G. SMOUT AND IMPERIAL CHEMICAL INDUSTRIES, LTD. Brit. 523,758, July 31, 1940 (Jan. 13, 1939).

Method and apparatus for removing the moisture from, and keeping dry, buildings, brickwork, etc. P. ERNST. Brit. 524,508, Aug. 21, 1940 (Jan. 31, 1939).

Wall construction. R. D. WOODWORTH. U. S. 2,213,355, Sept. 3, 1940 (Dec. 21, 1939).

Refractories

Effect of fluxes on the resistance to moisture and refractoriness of dolomite products. A. S. BAZILEVICH. *Ogneupory*, **7** [9] 585–92 (1939).—To obtain dolomite refractories of high resistance to moisture, silicoaluminous additions (kaolin, bauxite, or clay) should be added to the mix; the addition of iron oxide to silica is recommended for the production of highly refractory and moisture-resistant dolomite products. M.V.C.

Electric furnaces with inclined walls. M. ZUEV. *Stal*, **1939**, No. 6, pp. 30–32.—In some electric arc furnaces the vertical walls were replaced by inclined walls. Results were as follows: (1) the durability of the walls and the roof increased; (2) the cost of refractory materials decreased; (3) capacity of the metal bath increased; (4) the cost of electrodes and electrical power decreased; and (5) the quality of the steel was improved. B.E.K.

Heat-insulation problems in steam power plants. E. T. COPE AND W. F. KINNEY. *Mech. Eng.*, **62** [6] 465–70 (1940).—Insulation and the refractory requirements of boiler-furnace walls are briefly described and illustrated. See *Ceram. Abs.*, **19** [5] 115 (1940). F.G.H.

Highly refractory dolomite products with a watery bond from clinker obtained by means of the synthesis of tricalcium silicate. D. A. NIRENSHTEĬN AND K. M. SHMUKLER. *Ogneupory*, **8** [1] 23–28 (1940).—The manufacture of highly refractory dolomite products from clinker was accomplished by direct synthesis of tricalcium silicate from dolomite with the addition of natural raw materials containing alumina and silica. The results show the possibility of producing moisture-resistant dolomite clinker which is basically composed of tricalcium silicate and periclase. The purest dolomite should be used, and it should not contain more than 3.5% SiO_2 and not more than 6% of the total of $SiO_2 + R_2O_3$. Diatomite and clays containing Fe are recommended as admixtures. M.V.C.

High-temperature gas-fired test furnace. C. L. THOMPSON AND HERMAN G. WILCOX. *Bull. Amer. Ceram. Soc.*, **19** [9] 336–37 (1940).

Increase in durability in laying open-hearth furnaces. N. DUBROV AND J. DROSDOV. *Stal*, **1939**, No. 1, pp. 15–18. B.E.K.

Manufacture and testing of silica brick containing Tarasov quartzites in crowns of open-hearth furnaces. G. B. TAUBIN. *Ogneupory*, **7** [12] 733–37 (1939).—The results show the high quality of the silica brick manufactured. M.V.C.

Manufacture and testing of silica brick made from Ovruch quartzites in the crowns of open-hearth furnaces. G. B. TAUBIN. *Ogneupory*, **7** [8] 535–46 (1939).—Ovruch crystallized quartzites (100%) are suitable for the manufacture of silica refractories. Silica brick manufactured from them were as stable as brick prepared from tertiary quartzites. These brick do not require special technological methods of manufacture. M.V.C.

Manufacturing refractories from Maidan-Vilskiĭ kaolins. V. S. KVITKO. *Ogneupory*, **7** [8] 523–29 (1939).—Laboratory studies of Maidan-Vilskiĭ kaolins made by the Ukrainian Refractory Institute showed that these kaolins are suitable for the production of semiacid refractories of high grade. M.V.C.

Methods for determining gas permeability. D. N. POLUBOYARINOV AND I. YA. ZALKIND. *Ogneupory*, **7** [9] 611–14 (1939).—Methods used in the determination of gas permeability of refractories are reviewed. A preliminary test with a simplified method based on the determination of the air pressure only is dealt with. M.V.C.

Physicochemical reactions occurring in silica brick in insulated crowns of open-hearth furnaces. I. S. SMELYANSKIĬ. *Ogneupory*, **8** [1] 29–36 (1940).—S. reviews the literature on the effect of thermal insulation on the stability of silica brick in crowns of open-hearth furnaces. He concludes that, under normal operation of open-hearth furnaces, insulated crowns will possess longer life than those which are not insulated. M.V.C.

Production of alumina from raw materials other than bauxite. G. GALLO. *Chim. ind. agr. biol.*, **15**, 88–93 (1939); *Chem. Abs.*, **34**, 4867 (1940).—Outlines are given of processes of extracting Al_2O_3 from clays (Germany) according to the formula $Al_2O_3 \cdot 2SiO_2 + 3(NH_4)_2SO_4 = Al_2(SO_4)_3 + 6NH_3 + 2SiO_2 + 3H_2O$, from nephelite (Russia) according to the formula $(Na,K)_2O \cdot Al_2O_3 \cdot 2SiO_2 + 4CaCO_3 = (Na,K)_2O \cdot Al_2O_3 + 2(2CaO \cdot SiO_2) + 4CO_2$, and from alunite (Japan).

Refractories at Noranda smelter. W. B. BOGGS. *Bull. Amer. Ceram. Soc.*, **19** [9] 338–40 (1940).

Refractory materials. J. ZEELANDER. *Mech. World & Eng. Record*, **107** [2791] 571–72 (1940).—A flowsheet in chart form shows eleven major operations which refractory raw materials such as fire clay, silica, semisilica, magnesia, and dolomite must undergo during the making of refractories. F.E.S.

Service of silica brick made from crystalline and amorphous quartzites in open-hearth furnaces. A. A. POPOV. *Ogneupory*, **7** [10–11] 692–700 (1939).—A comparison is made of the stability of silica crowns in open-hearth furnaces in the U. S., Germany, and U.S.S.R. Tables showing their comparative properties are given. Silica brick for crowns may be manufactured from either crystalline or amorphous quartzites provided that their specific gravity is not over 2.38. M.V.C.

Technology, properties, and uses of forsterite (dunite) refractories. D. A. KISSIN. *Ogneupory*, **7** [10–11] 667–87 (1939).—K. discusses in detail the basic properties of raw materials; the manufacture and physicochemical properties of forsterite refractories and their use in metallurgical furnaces are also discussed. M.V.C.

Tertiary quartzous sandstone as raw material for silica brick. S. V. POTAPENKO. *Ogneupory*, **7** [9] 621–26 (1939).—On the basis of physicochemical and technological experiments, P. found that well cemented quartzous sandstones can be used as raw material for silica brick. These sandstones consist of quartz grains and siliceous cement in which the quartz grains are imbedded. Cement consists of very small quartz granules and crystalline secondary quartz, small amounts of clay substance, and oxides of titanium and iron. M.V.C.

PATENTS

Firebrick wall construction. W. A. WAITE. U. S. 2,212,411, Aug. 20, 1940 (July 18, 1938).

Furnace wall construction. W. A. WAITE. U. S. 2,212,412, Aug. 20, 1940 (April 14, 1939).

Making chromite refractory materials. G. E. SEIL (E. J. Lavino & Co.). U. S. 2,214,353, Sept. 10, 1940 (Jan. 13, 1939).—The process of making chromite refractories comprises mixing the chrome ore with an amount of barium oxide-yielding material so calculated that the BaO to SiO_2 ratio in the mixture is substantially 5.1 to 1 and heating the mixture to a temperature above the critical point at which barium orthosilicate is formed from the BaO and SiO_2 present but below the fusion point of the mass.

Manufacture of refractory material. BASIC DOLOMITE, INC. Brit. 523,581, July 31, 1940 (Jan. 15, 1938).

Producing nondeteriorating refractory products. MAGNESITAL G.M.B.H. Ger. 685,021, Nov. 16, 1939 (Jan. 21, 1935); VI/80*b*. 8.18.—The preformed mass is provided with a combustible covering such as paper, a metal layer which will oxidize upon firing, or a metal oxide layer. The pulverized oxide of a metal such as Al_2O_3 may be dusted on the object, after which it is given a final pressing and fired. A honeycombed system or form of metal oxide or combustible material may be placed in the form for pressing the material, the inserted system and the form for pressing the material is filled with the substance to be pressed, and the object is cast and fired. D.A.B.

Producing refractory materials. DIDIER-WERKE A.-G. Ger. 679,915, July 27, 1939 (April 3, 1936); VI/80*b*. 8.04.—Addition to Ger. 437,107.—Refractory materials are produced according to Ger. 437,107. Magnesite or materials containing magnesium oxide and chrome ore are finely ground and intimately mixed. A portion of this batch is cast, fired, and granulated. This material is added to the remainder of the finely ground mixture, and the cast object is fired. D.A.B.

Producing refractory products. KRISTOFFER STENVIK (V. M. Goldschmidt). Ger. 686,569, Dec. 14, 1939 (April 16, 1937); VI/80*b*. 8.18.—Refractory products are produced from magnesium orthosilicate or from materials containing this material, such as olivine rock, with or without the addition of other refractory materials, such as sintered magnesite, chromite, or both. Metals (for best results, those of the iron group) or alloys of metals in finely divided state are introduced to the starting materials, and, upon firing of the mixture, refractory cementing is produced by the transformation of the added metals into metallic oxide compounds. D.A.B.

Refractory mold material. A. W. MERRICK AND P. H. BEIER (Austenal Laboratories, Inc.). U. S. 2,211,789, Aug. 20, 1940 (Nov. 19, 1937).—Refractory mold material for making molds into which high-melting point metals and alloys are to be cast comprised essentially of ground quartz and comprising, in addition thereto, a binding agent and up to approximately 1.0% of an alkali oxide selected from the group consisting of sodium, potassium, and lithium introduced as a constituent of an inert carrier comprising soda-lime glass, the inert carrier being substantially insoluble and thereby avoiding any disturbance of the normal setting of the binding agent, the alkali oxide accelerating the transformation of quartz into tridymite at reduced temperature and being introduced in such amount that the resulting expansion is substantially limited at the final casting temperature and is not further increased by continued heating at the casting temperature for an interval of time after the casting temperature is reached.

Vertical retorts for the distillation of carbonaceous materials. WEST'S GAS IMPROVEMENT CO., LTD., F. J. WEST, AND E. WEST. Brit. 524,309, Aug. 14, 1940 (Jan. 26, 1939).

Terra Cotta

PATENTS

Ceramic vault. R. S. DONAHEY. U. S. 2,213,187, Sept. 3, 1940 (March 31, 1937).

Electrical conduits. ASSOCIATED CLAY INDUSTRIES, LTD., AND F. PACKARD. Brit. 523,820, Aug. 8, 1940 (Jan. 16, 1939).

Fireproof building structure. J. H. YOUNG AND P. W. JENKINS (H. H. Robertson Co.). U. S. 2,213,603, Sept. 3, 1940 (Oct. 14, 1938).

Flue lining. LEONIDAS WILSON. U. S. 2,213,354, Sept. 3, 1940 (June 14, 1938).

Glazing hollow clay bodies. R. A. SHIPLEY (National Fireproofing Corp.). U. S. 2,212,622, Aug. 27, 1940 (Aug. 18, 1938).

Machine for cutting tile, etc. C. A. MARTIN. U. S. 2,213,011, Aug. 27, 1940 (Dec. 18, 1939).

Producing a vitreous or glass-like surface on objects having several surface layers. MAURIZIO KORACH AND ANTONIUS DAL BORGO. Ger. 686,836, Dec. 21, 1939 (April 15, 1936); VI/80*b*. 14.01.—A glassforming or glazing material is applied to a nonsintered pulverized material which acts as an intermediate layer between the glazing and the correspondingly fashioned base. The object is heated until fusion and flowing together of the vitreous material. D.A.B.

Talc-containing ceramic composition. DONALD HAGAR. U. S. 2,213,495, Sept. 3, 1940 (Aug. 10, 1939).—A new ceramic composition for tile and other light glazed articles comprises as essential elements 5 to 45% talc and 0.1 to 5% barium carbonate, the remainder of the composition being composed of clay, flint, and feldspar.

Whiteware

Alternating-current resistance of ceramic materials at temperatures up to 600°C. E. F. RICHTER. *Physik. Z.*, 40, 597–603 (1939).—Test pieces of a porcelain body and two magnesium-silicate bodies consisted of round disks, 80 mm. in diameter and 5 mm. thick, coated with a fired-on platinum and silver electrodes. The entire equipment (insulators, thermocouple, etc.) was mounted on a small carriage which was pushed into the test muffle furnace. The heating-up time was 3 hr. and the cooling time was 9 hr. Measurements were taken during the heating-up and cooling of the specimens. The specific resistance in ohms per cm. at the normal 50-cycle frequency and at higher frequencies was plotted in diagrams (resistance vs. temperature (°C.)). The surface of the disks was found to have a decided influence upon the resistance. Porcelain specimens with ground-off surfaces showed an increase in resistance of 20 to 40%, while magnesium-silicate bodies with ground-off surfaces decreased in resistance from 40 to 70%. The combined value of the dielectric loss and the dielectric constant (expressed as $\epsilon \times tg\delta$) of each material gives a much more comprehensive picture in its relation to temperature when plotted in these diagrams than the separate values of loss factor and dielectric constant. 1 photograph, 8 diagrams. See "Electrical. . .," *Ceram. Abs.*, 17 [11] 358 (1938). L.E.T.

Ceramic filters. GINO CAMPANA. *Ceramica*, 2 [4] 120–26 (1940).—Ceramic filters have been used in the chemical, pharmacological, and bacteriological industries only in the last few decades. The particular property of sterilizing and filtering liquids containing microorganisms which certain fired masses with a kaolin base possess was first observed in the laboratory of Pasteur. With ceramic filters, solutions can be sterilized cold if necessary. Industrial filters resist high pressure, last longer, and can be renovated; some types are resistant to concentrated acids and alkalis. Some are made of glass wool, ceramic agglomerates, porous porcelain, and compact masses of diatomaceous earth. Agglomerates for filters are of different substances: glass, clay clinker, porcelain, quartz, etc.; they are ground to different finenesses (from 3600 to 4900 mesh up to 10,000 mesh per sq. cm.), compressed in a hydraulic press (300 to 400 atmospheres) into plates, cylinders, etc., of the desired dimensions, and fired at temperatures ranging from 800° to 1300°, depending on the material. The surface of the finished filter shows visible pores which lead to very small internal capillary canals of $^1/_{1000}$ to $^1/_{10}$ mm. constituting an intricate labyrinth. The clarifying power of agglomerates resides principally in the great surface of contact in the interior of the mass. The liquid passing through it loses bodies in suspension because of their ad-

hesion to the canal walls. Diatomaceous earth used for filters must be very pure. Its high clarifying power is derived from its great adhesive capacity because of the very large surface of contact existing between the microscopic reticulated silica particles, and for this reason it can be used for filtering microorganisms of a bacteria culture. The manufacture of diatomaceous earth filters, usually called "candles" because of the form of the filtering element, is very complex and requires the utmost accuracy and precision. The preparation of porcelain filters requires special care and is described briefly. Among the other uses of ceramic filters are the purification of drinking water in large plants and home installations and the clarifying of mineral and vegetable oils. M.V.C.

PATENTS

Ceramic body for spark-plug insulators. T. G. McDougal, A. H. Fessler, and H. B. Barlett (General Motors Corp.). U. S. 2,214,931, Sept. 17, 1940 (Sept. 7, 1938).—A spark-plug insulator characterized by high thermal efficiency, superior resistance to heat shock, good mechanical strength, and high electrical resistance at both high and low temperatures, in the form of a dense, nonporous body consisting of a sintered mixture of corundum and 0.5 to 20% monazite sand.

Ceramic distributor head. Otto Ellinger. Ger. 686,731, Dec. 21, 1939 (Nov. 29, 1938); *Ia/46c*[3]. 20.—A design is given for a ceramic distributor head made of steatite, calcite, etc. D.A.B.

Ceramic insulator. Ernst Albers-Schönberg (Steatit-Magnesia A.-G.). Ger. 679,917, July 27, 1939 (May 8, 1937); VI/80*b*. 8.08.—A ceramic insulator for steam boilers makes use of known ceramic materials whose essential constituents are related to the system MgO–Al_2O_3–SiO_2 and which have a composition by weight of 5 to 18 MgO, 30 to 50 Al_2O_3, 40 to 65% SiO_2, and heavy metal oxides such as iron oxide. This ceramic insulator is used in places on steam boilers where there is considerable heat change and the possibility of attack by superheated water. D.A.B.

Ceramic thread guide, etc. Hans Thurnauer (American Lava Corp.). U. S. 2,214,703, Sept. 10, 1940 (Nov. 17, 1937).—Textile-thread guides made of titanium dioxide are manufactured according to ceramic methods and fired to a vitrification temperature between 1350° and 1400°C. in a neutral or oxidizing kiln atmosphere.

Defecator with universal wall or floor outlet connection. W. C. Groeniger (John B. Pierce Foundation). U. S. 2,212,518, Aug. 27, 1940 (Nov. 17, 1937).

Pottery ware processing apparatus. W. H. L. Anderson, M. H. King, and A. W. McElroy (Edwin M. Knowles China Co.). U. S. 2,213,426, Sept. 3, 1940 (March 4, 1939).

Producing transparent vitreous objects. J. H. Partridge and Marcello Pirani (Patent-Treuhand-Ges. für elektrische Glühlampen m.b.H.). Ger. 679,916, July 27, 1939 (March 29, 1938); VI/80*b*. 8.07.—Transparent vitreous objects with a melting point above 1500°C. are produced from a pulverized mixture of at least 85% aluminum oxide and silicon dioxide, 1% thorium oxide, and 2% beryllium oxide, magnesium oxide, or a mixture of both. The batch is sintered closely near the melting point. D.A.B.

Shielded spark plug. L. A. Hyland (Bendix Aviation Corp.). U. S. 21,550, Sept. 3, 1940 (Feb. 26, 1935); reissue of original 1,950,408, March 13, 1934.

Spark plug. Milton Beckett. U. S. 2,212,893, Aug. 27, 1940 (May 4, 1939). C. E. Gotterba and A. R. Layer (August R. Layer). U. S. 2,214,958, Sept. 17, 1940 (April 24, 1939).

Spark plug. Tullio Tognola (Bendix Aviation Corp.). U. S. 2,214,781, Sept. 17, 1940 (June 25, 1938).—In a spark plug, a body portion, insulating means lining the walls of the body portion, an insulated electrode therein, the insulated electrode being surrounded by a stack of insulating disks, a metallic ring having a high coefficient of expansion mounted between the insulated walls of the body and the insulated central electrode and between the insulating disks whereby heat expansion of the metallic ring compresses the insulating lining, the insulation surrounding the central electrode, and the stack of insulating disks.

Spark plug with ceramic insulator. Otto Beesch (Robert Bosch G.m.b.H.). Ger. 685,176, Nov. 16, 1939 (Nov. 27, 1937); *Ia/46c*[3]. 60.02.—A design is given for a spark plug with a ceramic insulator. D.A.B.

Spark plug temperature control. P. G. Andres (Bowes "Seal-Fast" Corp.). U. S. 2,212,725, Aug. 27, 1940 (Aug. 18, 1939).

Testing electrical insulators. Bushing Co., Ltd., and W. J. Brown. Brit. 524,862, Aug. 28, 1940 (Jan. 13, 1939).

Thermionic valves having ceramic bases. M-O Valve Co., Ltd., J. Richards, and G. W. Warren. Brit. 524,815, Aug. 28, 1940 (Feb. 7, 1939).

Water closets, etc. W. C. Groeniger. Brit. 524,423, Aug. 21, 1940 (Feb. 15, 1938).

Equipment and Apparatus

Accurate timing equipment for viscosity determinations. E. M. Fry, Jr., and E. L. Baldeschwieler. *Ind. Eng. Chem., Anal. Ed.*, **12** [8] 472–73 (1940).—A method and apparatus for obtaining accurate timing for short intervals are described. The accuracy is better than ±0.1% for intervals of 100 sec. and over. Illustrated. F.G.H.

Better feeding means better screening. Royal E. Fowle. *Rock Products*, **43** [3] 29–32 (1940).—F. describes the various types of feed chutes in use in rock, gravel, and cement plants. Illustrated. J.J.H.

Characteristics of cloth filters for coal dust-air mixtures. A. R. Mumford, A. A. Markson, and T. Ravese. *Trans. Amer. Soc. Mech. Engrs.*, **62** [4] 271–81 (1940).—The installation, operation, and maintenance of cloth filters for handling vented air from pulverized-coal mills are dealt with. The experiences of the authors in solving problems in connection with the cloth-bag filter system, as used at the Kip's Bay Station of the New York Steam Corporation, are the basis on which the subject is developed. Complete performance tests on a 40-ton mill installation are cited. Illustrated. F.G.H.

Clinker cooling. A. W. Catlin. *Rock Products*, **43** [2] 31–32 (1940).—C. discusses the efficiency of clinker coolers used in the cement industry. J.J.H.

Constant dust-feeding device for laboratory use. C. E. Williams and W. P. Battista. *Jour. Ind. Hyg. & Toxicol.*, **22** [4] 152–53 (1940).—In studying dust control and other dust problems in the laboratory a method of introducing dust into an air stream at constant rates is necessary. An inexpensive apparatus having a maximum capacity of approximately 3 lb. per min., which has worked successfully with several typical industrial dusts, is described. The machine was designed with a capacity sufficient for loading air streams with 15 to 20 gr. of dust per cu. ft. in a maximum air volume of approximately 1000 cu. ft. per min. Illustrated. E.J.V.

Construction of portable electrical overhead systems. L. W. Birch. *Mining Congr. Jour.*, **26** [7] 32–33 (1940). W.D.F.

Flow pattern and pressure drop in cyclone dust collectors. C. B. Shepherd and C. E. Lapple. *Ind. Eng. Chem.*, **32** [9] 1246–48 (1940).—The friction loss in a cyclone was observed to increase twofold when the cyclone inlet vane employed in the previous tests was shortened so that no part of it extended into the cyclone chamber. Spiral velocities within the cyclone reflected a corresponding increase. Velocity traverses made with an improved Pitot tube indicated that, for larger radii, the spiral veloc-

ity increased approximately as the inverse square root of the radius, but, at a radius of approximately one third that of the cyclone cylinder, the spiral velocity began to decrease as the radius decreased. Illustrated. See *Ceram. Abs.*, **19** [2] 49 (1940). F.G.H.

Healthy air in the workshop. PAUL MENSING. *Gesundh.-Ing.*, **62** [47] 665–67 (1939).—The idea of healthy air in the workshop must be more widely accepted by the public. The article, which is of highest interest to employers and contractors, shows the ways and means of replenishing the air in the workshop. Windows, airing shaft, mechanical airing appliances, table ventilator, ceiling ventilator, airing apparatus, dissipating systems, and air heating apparatus are discussed. W.D.K.

Improving grinding: I–III. C. D. RUGEN, J. A. KIVERT, AND R. E. BOEHLER. *Rock Products*, **43** [3] 33–34; [4] 31–32; [5] 35–37 (1940).—Factors affecting the operation of grinding circuits and methods which have been used successfully to improve their performance are reviewed. Charts are included. J.J.H.

Measuring average particle diameter of powders. Air-permeation apparatus. ERNEST L. GOODEN AND CHARLES M. SMITH. *Ind. Eng. Chem., Anal. Ed.*, **12** [8] 479–82 (1940).—A self-calculating apparatus for the direct determination of the surface-weighted average particle diameter of powders has been designed and subjected to practical tests. It consists of a device for determining the average or effective particle diameter of a powder, as deduced through Carman's specific surface equation, from its permeability to air when the sample is formed into a compact bed. The operation of the device is remarkably convenient, simple, and economical regarding both time and material. The automatic calculating feature reduces to a minimum the work of a determination and the chances of making mistakes. In precision and accuracy the method compares favorably with the usual methods of granulometric analysis for powders. Illustrated. F.G.H.

Measuring temperatures. L. LOUIS MULDER. *Gesundh.-Ing.*, **62** [48] 677–82 (1939).—M. describes various kinds of temperature measuring. The measuring of the temperature of solid materials, liquids, and gases and vapors and that of alternating temperatures are discussed. Practical examples are given. W.D.K.

Meter for controlling temperature and humidity in plants. G. BRÜCKNER AND SCHMIDT. *Gesundh.-Ing.*, **62** [45] 651 (1939).—The kinds of instruments and their possibilities for certain uses are discussed. W.D.K.

Microscopic method for Portland cement in dust samples. IRWIN A. PEARL. *Ind. Eng. Chem., Anal. Ed.*, **12** [8] 492–93 (1940).—Illustrated. F.G.H.

Principles of comminution: I, Size distribution and surface calculations. R. SCHUHMANN, JR. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1189; *Mining Tech.*, **4** [4] 11 pp. (1940).—S. gives the results of a study of the Gaudin and Rosin-Rammler equations to develop a size distribution equation that is more usable, viz., $y = 100 \times (x/k)^m$, where y is cumulative per cent finer than x, x is screen size opening, k is a constant with dimensions of particle size, and m is a constant (the distribution modulus). A plot of log y vs. log x gives a straight line of slope m, and the intercept at 100% gives k. The specific surface of particles of size k is then calculated and multiplied by $100m/(m-1)$; a point is located with this value as ordinate and k as abscissa on log paper, and a line with slope $(m-1)$ is drawn. This line gives the specific surface of the particles. The linearity of the cumulative curve was found satisfactory on seven sets of particle size data from different workers which included the extremes of quartz, coal, and galena. This equation gives straighter curves than the Rosin-Rammler equation. Quartz (1 to 1½ in.) was crushed to ⅜ in. in a laboratory jaw crusher and sized by screens and a sedimentation balance. It gave a straight line below 0.6 mm., which fraction has only 15% of the weight but over 90% of the surface. Extrapolation of the curve to 0.01 and 0.001 mm. shows that, with the crushed quartz, 80 to 85% of the surface is on particles below 400-mesh. W.D.F.

Proportioning raw materials. NATHAN C. ROCKWOOD. *Rock Products*, **43** [8] 36–39 (1940).—R. describes and discusses the application of various types of continuous weighing and batch feeders used in the cement industry. Illustrated. J.J.H.

Sampling cement materials. NATHAN C. ROCKWOOD. *Rock Products*, **43** [8] 47–51 (1940).—R. describes and discusses the use of various types of samplers used in the cement industry. Illustrated. J.J.H.

Seeing with electricity. JEAN HARRINGTON. *Sci. Amer.*, **163**, 20–22 (1940).—The electron microscope is closely analagous to the ordinary microscope; it uses electrons instead of light and either magnetic or electrostatic fields for lenses. It is possible to study such things as bacteria supported on a collodion film, the edge of a razor blade, or the surface of an electrode by the electrons it emits. The resolving power is much higher than that of the ordinary microscope but it is nowhere near the theoretical limit. The magnetic lenses have aberrations similar to those of ordinary lenses, and distortion of the image occurs if the fields are not symmetrical, if the accelerating potentials (50,000 to 100,000 volts) vary a volt or two, or if the electrons are slowed too much when passing through the specimen. W.D.F.

Slurry screens reduce grinding cost. ALBERT E. REED. *Rock Products*, **43** [8] 61–62 (1940).—R. describes and discusses the application of slurry screens used in connection with the grinding of slurry in the cement industry. Illustrated. J.J.H.

Special connection for pyrometry by thermocouple. H. DE RYCKER. *Rev. Universelle Mines*, **14** [3] 299–301 (1938).—The accuracy of temperature measurement by the thermocouple is increased by compensating the error due to the voltage drop in the thermocouple and the leads by a shunt resistance. The theory of the circuit is explained. M.H.

Thermal stresses in cylindrical pipes. HILLEL PORITSKY. *Phil. Mag.*, **24** [160] 209–23 (1937).—Stresses in a cylindrical pipe at a steady-state temperature are mathematically treated for cases where the ends of the pipe are and are not restricted. A complete analytic solution is obtained; this is made possible by the fact that temperature itself is a harmonic function. H.H.S.

Wear-resisting metals. WILLIAM A. GIBSON. *Rock Products*, **43** [8] 28 (1940).—G. discusses the use of impact- and wear-resisting welding rods and castings for the various wearing parts of pulverizers and grinders. Some very high-priced coating materials have not proved as successful as the cheaper ones. This may be due to the fact that some coating metals which show a very high Brinell hardness have a tendency to spall when put in operation, whereas the cheaper metals seem to fuse into the parent metal, giving better results. Before welding rods are used, they are subjected to an impact test on a machine designed for this purpose. J.J.H.

SEPARATE PUBLICATIONS

Ore-Dressing Studies: Properties of Suspension Mediums for Float-and-Sink Concentrations. Metallurgical Division Progress Report No. 32. F. D. DEVANEY AND S. M. SHELTON. *U. S. Bur. Mines Repts. Investigations*, No. 3469, revised. 24 pp. Free.—The properties of suspensoids and the problems met in float-and-sink ore concentration in suspension media are reviewed. R.A.H.

Testing and Design of Respiratory Protective Devices. H. H. SCHRENK. *U. S. Bur. Mines Information Circ.*, No. 7086, 11 pp. Free.—S. describes various respiratory protective devices and shows how they are tested to meet the requirements of the Bureau's schedules. R.A.H.

PATENTS

Apparatus for batch weighing. C. L. HARMON (C. S. Johnson Co.). U. S. 2,212,419, Aug. 20, 1940 (Nov. 9, 1938).

Ball mill. ANDREW PERENY. U. S. 2,212,452, Aug. 20, 1940 (Nov. 5, 1938).

Deaired wire-cutting press, clay cutter, etc., for plastic materials. EMANUEL DÜRST AND OSKAR DÜRST. Ger.

684,567, Nov. 9, 1939 (Jan. 28, 1938); VI/80*a*. 26.—A deaired wire-cutting press, clay cutter, etc., is provided with an escapement device for the passage of the plastic mass which serves for the regulation of the output of the preliminary press. It is arranged near the filling opening of the preliminary press, especially between the worm shaft and the worm screw blades of the preliminary press. D.A.B.

Deairing wire-cutting press. EMANUEL DÜRST AND OSKAR DÜRST. Ger. 685,078, Nov. 16, 1939 (Dec. 6, 1933); VI/80*a*. 26.—A deairing wire-cutting press has a preliminary press worm screw and a main press worm screw on a common shaft, which has an interior bushing for the shaft unit. The arrangement of the bushing in the deairing chamber is such that both faces of the bushing are exposed to the effect of the diminished pressure. D.A.B.

Drying unit for roofing tile, etc. C. KELLER & Co. Ger. 689,801, March 14, 1940 (Oct. 21, 1937); V/82*a*. 2.—The forms are placed in individual compartments having slanting side walls and provided with openings for the circulation of air. These are lowered into the drying chambers. D.A.B.

Equipment for plasticizing. DAVIS BROWN. U. S. 2,213,381, Sept. 3, 1940 (Oct. 24, 1939).—In a device for use in mixing and treating ceramic materials, the combination of a mixer of substantially U section provided with a dome cover adjacent one end thereof, an opening in the side of the mixer beneath the dome cover, a longitudinally extending shaft in the mixer, mixing blades carried by the shaft, an auger element carried by the shaft under the dome cover, pusher elements carried by the shaft between the auger and the end of the mixer, the pusher elements being adapted to discharge material through the opening, a single series of horizontally and inwardly extending stationary comb elements carried by the inner surface of the mixer on the side of the opening, the elements resisting upward movement of material in the mixer when the shaft is rotated.

Forming ceramic bodies. H. J. GALEY (N. S. Garbisch). U. S. 2,215,214, Sept. 17, 1940 (Dec. 16, 1938).—A process of forming a ceramic body comprises placing a predetermined quantity of a mixture comprising about 75 to 80% of finely divided silica and about 15 to 25% of finely divided glass in a pan of substantially the same cross-sectional dimensions as the body to be formed and consisting of relatively thin, heat-resistant sheet metal, preliminarily heating the mixture in the pan to a temperature above the point of sintering of the glass but not substantially above 1700°F. to sinter the glass, putting the pan with the heated mixture therein in a strong mold having side walls defining a chamber of substantially the same cross-sectional dimensions as the pan and subjecting the mass while relatively loose and uncompacted to intense mechanical pressure in order to consolidate the material into a strongly coherent state, removing the pan and the pressed body therein from the mold, cooling them, and taking the body from the pan.

Horizontal or vertical worm screw press, clay cutter, etc., for the working and formation of ceramic masses. GOTTFRIED WELZEL (G. P. Welzel). Ger. 687,172, Dec. 28, 1939 (Jan. 21, 1938); VI/80*a*. 26. Addition to Ger. 678,466 ("Endless. . .," *Ceram. Abs.*, **19** [2] 50 (1940)).—A worm screw press providing for the introduction and working of a ceramic mass in shredded form according to Ger. 678,466 has the turning cylinder provided with a number of openings. D.A.B.

Horizontal wire-cutting press for plastic materials such as clay. RICHARD RAUPACH MASCHINENFABRIK GÖRLITZ G.M.B.H. Ger. 686,672, Dec. 21, 1939 (Aug. 12, 1935); VI/80*a*. 26. Addition to Ger. 638,477.—A horizontal wire-cutting press according to Ger. 638,477 has a smaller roller which is opposite the entrance roller and which is driven in the opposite direction. The joining or connecting gap, marked by the two rollers, between the upper and lower section of the deairing chamber starts at some distance from the entrance side of the chamber. D.A.B.

Metallurgic weighing apparatus. A. A. FREY AND E. J. PARSONS. U. S. 2,213,982, Sept. 10, 1940 (April 23, 1938).—A molten metal weighing apparatus.

Rotary tube furnace for firing, calcining, roasting, and sintering charges of all kinds. REINHOLD DIETZE. Ger. 689,239, Feb. 22, 1940 (Dec. 4, 1936); V/80*c*. 14.01.—A rotary tube furnace for firing, etc., charges of all sorts has regularly spaced radiation banks in its interior, which are arranged one after another in a helical line in such a manner that they regulate the gases passing through the furnace and produce by force a twisting movement of the gases. D.A.B.

Silicon carbide heat resistance for electric resistance furnaces. SIEMENS-PLANIAWERKE A.-G. FÜR KOHLEFABRIKATE. Ger. 684,523, Nov. 9, 1939 (June 13, 1936); VIII*c*/21*h*. 15.01.—A SiC heat resistance for a heavy walled electrical resistance furnace has reinforced ends. These ends are made small in relation to the wall strength and are fastened at intervals into the wall by a metallic or graphite lead. The walling is provided with a water cooling system. D.A.B.

Sintering machine. R. W. HYDE AND R. D. PIKE. U. S. 2,213,396, Sept. 3, 1940 (Sept. 14, 1939).

Wire-cutting press. ERDMANN VOGT (Richard Raupach Maschinenfabrik Görlitz G.m.b.H.). Ger. 686,673, Dec. 21, 1939 (May 24, 1938); VI/80*a*. 28.—In a wire-cutting press, the die for forming holes in material passing through the wire cutter is automatically centered; the die is fastened to the end of the worm screw shaft by means of a long thin rod and a special joint for the rod. The die is rigidly fixed onto the rod, and the rod is fastened loosely to the end of the worm screw shaft by means of a ball bearing joint. D.A.B.

Worm press for shaping ceramic charges. G. P. WELZEL. Ger. 684,045, Nov. 2, 1939 (May 9, 1936); VI/80*a*. 26.—A press for fashioning ceramic charges has a mixing and prepressing worm above the main press. The prepressing worm extends over almost the entire length of the main pressing worm, and the charge is introduced to the main pressing worm by means of a common filling tube opposed to the feeding direction of the main worm and is fed into a chamber fixed at the far end of the main worm through a mouthpiece with a separating unit of thin disks, etc.; this chamber serves as the deairing chamber. D.A.B.

Kilns, Furnaces, Fuels, and Combustion

Application of heat transfer data to furnace walls and roofs. F. A. FAVILLE AND GEORGE ELLERTON, JR. *Iron & Steel Engr.*, **16** [10] 60–68 (1939).—Graphical charts are given to facilitate the calculation and checking of heat losses through walls. B.L.

Conditioning heavy fuel oil. J. H. HOPKINS. *Ind. Heating*, **7** [2] 132–34 (1940).—With the continuous progress in refining raw oil the residues used as fuel oil have become heavier, leaving much sludge in the storage tanks and causing trouble in the piping system and burners. H. describes the Volcanic Oil Mill which has a rotary pump which conditions oil and sludge by breaking it up into fine particles in attrition chambers in the pump before going into the piping system; this eliminates burner trouble and also frequent and costly tank cleaning. The combustion is more perfect and does not leave a smudge on checkers or refractory parts. Mills capable of processing 6000 gal. per hr. of heavy fuel oil have been installed. M.H.

Controlled atmospheres for modern furnaces. H. M. HEYN. *Ind. Heating*, **7** [8] 683–88, 692 (1940).—H. discusses the various processes of heat-treating metals in definite atmospheres, defines terms applied for different

processes, and describes gases used and their production. The gases most used for protective atmospheres are as follows:

Type of prepared atmosphere gas	Gas constituents (%) O_2	CO_2	CO	H_2	CH_4	H_2O	N_2
DX-gas, lean, 40°F. dew point	0	10.5	1.5	1.2	0	0.8	86.0
DX-gas, rich, 40°F. dew point	0	5	10.5	12.5	0.5	0.8	70.7
Girbotrol, DX-gas	0	0	1.5	1.2	0	0	97.3
CG-gas produced at 1800°F.	0	0.2	20.5	36.0	3.8	0	39.5
Char-gas produced at 1800°F.	0	0.1	34.0	8.0	0.3	0	57.6
Charmo-gas produced at 2800°F.	0	0	34.7	2.5	0	0	62.8
Dissociated ammonia	0	0	0	75	0	0	25

As an atmosphere, a DX gas (lean) is satisfactory for most nonferrous metals, and when it is dried to a 40°F. dew point it will bright anneal low C steel. Rich DX gas can be used for annealing and hardening medium C steels when the cycle of heat treatment is not more than about 30 min. CG or cracked gas carburizes low and medium C steels and can be used for annealing the higher C steels. It can also be used as an atmosphere for clean hardening medium and high C steels. An atmosphere correctly made from charcoal is carburizing and can successfully be employed for clean hardening and bright annealing medium and high C steels. N gas, being inert, is suitable for clean hardening and bright annealing medium and high C steels but, as it reacts very quickly with air and other gases, great care must be taken in its application. M.H.

Development of a laboratory continuous kiln. C. H. Commons, Jr., and E. E. Kunzman. *Bull. Amer. Ceram. Soc.*, **19** [9] 331–33 (1940).

Effect of coal characteristics on pulverized-coal firing. Ollison Craig. *Mech. Eng.*, **62** [6] 452–54 (1940).—Properties affecting the burning of coal in pulverized form are (1) volatile matter, (2) fixed carbon, (3) agglutination, (4) swelling, (5) ash, (6) ash-fusion temperature, (7) moisture, (8) sulfur, and (9) grindability. The manner in which these coal properties affect carbon loss, excess air, and slag is discussed in detail. The effects of the design of the furnace, the design of the burners, and the characteristics of the pulverizer are described briefly. Results obtained from pulverized-coal firing are given. F.G.H.

Heat loss in enameling and glassmelting furnaces. Otto T. Koritnig. *Glashütte*, **70** [21] 265–67 (1940).—Heat losses vary with different kinds of furnace construction and different types of ware. In enameling metal it is important to know whether the metal has been cast or rolled because of the necessity of regulating the firing time and temperature to avoid heat losses from incorrect firing. Definite heat losses also occur in furnaces for firing glass (pot and tank), annealing furnaces, and gas generators. Heat losses from conduction, radiation, convection, and escape occur at the heat source, in conduit, and at the place of use and reduce the thermal efficiency of the plant. Only a fraction of the heat produced is used for actually fusing the charge, and it is conditioned by the construction of the furnace, method of operation from a heat technical standpoint, and the degree of care exercised in tending the furnace. The heat loss from (1) walls, (2) waste gases, (3) tending the furnace, and (4) residual losses can be analyzed. (1) Heat losses from the walls occur because the hot gases heat not only the charge but also the entire interior of the furnace; although some of the heat is reflected from the masonry onto the charge, a large part penetrates deep into the masonry and may pass through it entirely, especially the crown. Poor insulation of the masonry causes great heat loss, especially in single furnaces. To investigate the loss of heat from the walls, holes are bored in the masonry at different depths, thermoelements are inserted, and the temperature is measured. If t_a = initial temperature of masonry at the beginning of firing, t_e = average temperature at the end of firing, G = weight of masonry (calculated from the furnace dimensions), and c = average specific heat of the masonry, then the heat stored in the masonry, Q_1, equals $G \times c \times (t_e - t_a)$ Cal. According to Langmuir's equation, the heat loss by radiation from the exterior of the furnace, Q_2, equals $0.838 \times (T_e - T_a)^{4/3}$ Cal./sq. m./hr., where T_a = temperature of the outer air and T_e = temperature of the furnace wall. The value for Q_2 can be ascertained from the law of Stefan-Boltzmann: $Q'_2 = n \times C_s \times (T_e^4 - T_a^4)$ Cal./sq. m./hr., where n = absorption ratio, C_s = radiation constant, and T_e and T_a = the same as above. Q_2 and Q'_2 should show fairly equal values. How far the heat can penetrate perceptibly can be determined empirically. The depth of this penetration depends on the duration of firing, the temperature in the firing chamber, the composition of the masonry, and the ratio of the thickness of the walls to the depth of penetration. If the material of the wall prevents the heat from passing to the exterior, heat is lost by accumulation in the walls, radiation, and convection. The quantity of heat lost in this way can be calculated by heat conductivity figures. If the temperature in the surface masonry is difficult to ascertain, by committing a small error the quantity of heat can be placed in proportion to the difference in temperature between the furnace wall and the air: $Q = \lambda \times (t_e - t_a)$ Cal./sq. m./hr., where λ = the total heat transfer figure for radiation and convection. The values for λ can be taken from the following table (*Mitt. Wärmestelle Ver. Deut. Eisenhüttenleute*, No. 51, p. 15):

Outer surface temperature of wall t_e	Total heat transfer figure for vertical or horizontal walls (Cal./sq. m./hr.)
10	7.4
25	8.6
40	9.6
60	10.9
80	11.6
100	12.4
130	13.8
160	15.2
200	17.4
240	19.3
280	21.4
320	24.1
350	26.1
400	29.8

Since these figures are applicable only for t_a temperatures which lie between −10° and +10°, they are not applicable for annealing in intervals of more than 30°C.; in the latter case λ is higher. The use of the table is illustrated: temperature of the furnace wall, t_e, = 60°, temperature of the outer air, t_a, = 16°; the quantity of heat given off in 1 hr. by 1 sq. m. by radiation and convection is calculated as $Q = 10.9 \times (60 - 16) = 480$ Cal. The heat lost by the wall can be reduced considerably by good insulation. (2) The loss of heat from waste gases occurs when heat is drawn off with the gases from the firing chamber and when the heat value of the combustion gases is not entirely consumed in the firing chamber. The perceptible quantity of heat is calculated: $W = R \times c \times (t_A - t_L)$ Cal. for 1 kg. fuel, where R = volume of gas for 1 kg. fuel, and c = average specific heat of the gas between the temperature t_A of the waste gas and t_L of the air for combustion; c can best be taken from tables in technical handbooks. Heat loss from waste gases can be greatly reduced by utilizing the waste gases for preheating unfired ware. (3) Service losses in operation of the furnace may be due to incompletely burned solid fuel which is thrown away or to the use of more fuel than is required for proper functioning and regulation of the furnace. Cracks in the furnace masonry or chimney and too strong a draft also cause service losses. (4) If the quantity of heat losses from walls, waste gases, and furnace operation are added together, the result rarely equals 100% of the heat produced; there is always a difference which is called the residual loss and includes all losses not covered by tests, e.g., heat loss through the furnace flooring, in flying ashes, etc. M.V.C.

Improved setting of annular kilns. O. Sch. *Tonind.-Ztg.*, **63** [3] 25–27 (1939).—S. discusses a new method of setting brick which decreases the resistance to movement of the fire gases and provides for a better distribution of the coal through the kiln. W.K.

Modern protective gases for electric-furnace operation and directions for preparing them. G. Simon. *Tech. Z. prakt. Metallbearbeitung*, **49**, 379–82 (1939); *Chem. Abs.*, **34**, 4993 (1940).

Radiation of furnace gases. A. Schack. *Arch. Eisenhüttenwesen*, **13** [6] 241–48 (1939).—The published data of other investigators were used as the basis of formulas for CO_2 and H_2O vapor radiation. The CO_2 radiation can be expressed as $q_{CO_2} = 3.5\sqrt[3]{ps}\left(\frac{T}{100}\right)^{3.5}$ Cal./m.²hr., where p is partial pressure and s is the thickness of the gas layer. For water vapor the formula becomes $q_{H_2O} = 35 \times p^{0.8} \times s^{0.8}\left(\frac{T}{100}\right)^3$. They can be used safely for the determination of gas radiation up to 450 °C. The radiation of nonluminescent flame is the same as that of corresponding amounts of CO_2 and H_2O vapor after the completion of the reaction, under similar conditions. Flame reactions do not increase the total amount of radiation. Hydrocarbon gases have a pronounced radiating power; carbon monoxide has less, while oxygen and nitrogen do not have any. Radiations of CO_2 and H_2O vapor follow different laws. The heat transfer of gases containing little carbon dioxide and much water vapor is pronouncedly greater than that of gases in which little water vapor is associated with much carbon dioxide. J.D.G.

Relation between the properties of graphitized electrodes and their particle size. M. S. Maksimenko and M. S. Vavilov. *Tsvetnye Metally*, **1939**, No. 8, pp. 62–68.—The effect of grain size on the mechanical strength, electric resistance, porosity, and stability of graphitized electrodes was studied with two groups of samples prepared from the following grain sizes: (1) 1 to 0.5, 0.5 to 0.15, and 0.15 to 0 mm. and (2) 0.5 to 0.15, 0.15 to 0.075, and 0.075 to 0 mm. The following conclusions were drawn: (1) there is no relationship between the specific gravity of the dry component of the electrode material and the properties of the electrodes; (2) increasing the fines in the mixture increases the mechanical strength of the electrodes and decreases the electrical resistance and the porosity; (3) the oxidizability increases with increasing fines in the mixture; and (4) electrodes prepared from coke grains of 1 mm. maximum size had lower mechanical strength and higher electrical resistance and porosity than those prepared from coke grains of 0.5 mm. maximum size. The effect of the granulometric composition on the mechanical strength will be reported in a following paper. A literature review with twenty references is included. B.Z.K.

Resistance heating units, their selection and application. M. M. Greer. *Product Eng.*, **11** [8] 351–53; [9] 414–16 (1940).—G. describes the different types and forms of heating by electric resistances and discusses the factors to be considered in selecting the units for a definite purpose. The conditions affecting ratings and the life of heating units are illustrated in curves and diagrams; permissible watts for immersion heaters for heating various liquids are as follows:

Material	Approximate temperature (°F.)	Watts/sq. in. surface of heater
Water, occasional or intermittent	212 maximum	40–60
Water, continuous	212	28–35
Oil, circulating	100–400	20–25
Oil, noncirculating	100–400	16–20
Lead	650–800	14–16
Molten salts	600–950	10–15
Asphalt-tar	200–600	6–8
Molasses	120	4
Glue	150	Should not be heated directly; a water bath should be used.

General directions for installation and wiring diagrams are given. M.H.

Stoker firing of kilns. J. E. Martin. *Bull. Amer. Ceram. Soc.*, **19** [9] 334–35 (1940).

SEPARATE PUBLICATION

Large-Scale Tests of the Explosibility of Coal Dusts Made in the U. S. and Great Britain. H. P. Greenwald. *U. S. Bur. Mines Repts. Investigations*, No. 3462, 9 pp. Free.—G. points out to what extent the divergent results obtained have been correlated. R.A.H.

PATENTS

Electrical heating element with metallic heat conductor and ceramic protective covering. Siemens-Schuckertwerke A.-G. Ger. 655,006, Dec. 16, 1937 (Sept. 4, 1936); VIII*c*/21*h*. 2.01. Reinhold Reichmann (Siemens-Schuckertwerke A.-G.). Ger. 684,656, Nov. 9, 1939 (March 24, 1937); VIII*c*/21*h*. 2.02.—Ger. 655,006 provides that materials which cause O_2 to combine with them at high temperatures or which split off gases that will combine with O_2 be placed in the intermediate chamber between the metallic heat conductor and the ceramic protective covering, there being a gap between the covering and introduced materials. Ger. 684,656 provides that only a fraction of the space remain empty between the heat conductor and the protective covering or that a corresponding larger space communicating with the protective space be filled with the materials capable of reacting with O_2 or materials splitting off gases which combine readily with O_2. D.A.B.

Geology

Barite deposits in northern Nevada. Vincent P. Gianella. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1200; *Mining Tech.*, **4** [4] 6 pp. (1940).—Barite is produced in nine of seventeen counties; the most important production is in the northern part of the state. G. describes occurrences in Lander, Eureka, and Elko counties. Barite occurs in veins with some sulfides and as replacement deposits in limestone. At Eagleville, Churchill Co., there is a 3-ft. vein in volcanics. Near Argenta, Lander Co., a bed 80 ft. wide on the outcrop and dipping 30° has replaced limestone. Near Hilltop a quartz and barite vein occurs. Near Simon Creek in Eureka Co. barite occurs in seams and veins in a limestone deposit, and there are many other wide veins in the same neighborhood. Near Corlin a 10 ft. vein is mined. The veins are probably of hydrothermal origin and range from Jurassic to late Tertiary. W.D.F.

Bauxite in world economics. E. Schuren. *Metallwirtschaft*, **19** [11] 209–12 (1940).—The ever-increasing importance of light metals in the last few years, particularly of Al and its alloys, necessitates a comprehensive survey of the deposits, richness, geographical distribution, and production of bauxite minerals. The largest deposits so far known are in the British Gold Coast Colony; the next largest are in Hungary, Yugoslavia, and British Guiana. Tables are given which show world production from 1929 to 1937; it amounted to 2141 long tons in 1929 and 3730 in 1937. Europe produced about $^2/_3$ and the U. S. about $^1/_3$ of the total. S. discusses the economic conditions from the viewpoint of the present political conditions; the production and consumption conditions in Great Britain, Canada, and the U. S. are treated in particular. M.H.

Clay deposits of California. W. F. Dietrich. *Bull. Amer. Ceram. Soc.*, **19** [9] 340–44 (1940).

Color reactions between clays and amines. E. A. HAUSER AND M. B. LEGGETT. *Jour. Amer. Chem. Soc.*, **62** [7] 1811–14 (1940).—The formation of colored compounds on clay is the result of a reaction between clay and aromatic amines. The influence of various substituents, acid and basic, is discussed. A preliminary hypothesis explaining the mechanism of the reaction is advanced. Illustrated. F.G.H.

Geology and world deposits of chromium minerals. J. HARROY. *Rev. Universelle Mines*, **15** [6] 290–304 (1939).—H. gives a comprehensive review and survey of the geology, petrography, and geographical and stratigraphical distribution of Cr-bearing ores. The metal exists in the form Cr_2O_3 in ultrabasic rocks, in basic, neutral, and acid (syenite and granite) rocks, and in rocks of later geological periods; the latter contain only 0.5% and porphyries only 0.01% Cr_2O_3. There are 55 known types of Cr minerals; of these, however, only a few silicates of magmatic or secondary hypogenous origin and chromates are of commercial importance. A table gives the chemical composition of the most important ore deposits which are in Norway, Yugoslavia, Greece, Russia, Turkey, British India, Southern Rhodesia, Transvaal, Sierra Leone, Cuba, Brazil, and the U. S. (California). The statistics of world production are included. Untouched Cr deposits are estimated at 825 million tons. M.H.

Hydration mechanism of the clay mineral montmorillonite saturated with various cations. S. B. HENDRICKS, R. A. NELSON, AND L. T. ALEXANDER. *Jour. Amer. Chem. Soc.*, **62** [6] 1457–64 (1940).—The hydrous magnesium aluminum silicate mineral montmorillonite, because of its unusual properties and widespread occurrence in clays and soils, has attracted the attention of workers in many fields. It is extremely plastic when moist and can be dispersed in water, readily forming thixotropic gels at moderate concentrations. The dispersed material reorganizes upon drying, forming a crystalline material, one lattice constant of which depends upon the humidity. Montmorillonite is a salt of a moderately strong acid from which other salts and the free acid can be prepared by cation replacement, i.e., base exchange. It strongly absorbs bases with the formation of the corresponding salts and also shows marked adsorption in the case of neutral organic compounds, which is the basis for its use as a clarifying agent. Many reactions are catalyzed by montmorillonite. The study of montmorillonite as a base-exchange complex has come about largely because it is a component of many soils showing high base-exchange capacity. For a number of years the authors have been interested in the identification and structures of minerals present in clays. During the course of this work it became evident that a study of water sorption by the various salts of montmorillonite probably would go far toward determining the environment of the replaceable cation. The material is one of the few in which sorption can be followed by means of lattice changes. The water sorptions at relative humidities between 5 and 90% were measured for Li^+, Na^+, K^+, Cs^+, Mg^{++}, Ca^{++}, Sr^{++}, and Ba^{++} salts as well as for the free acid of montmorillonite. Variations in X-ray diffraction patterns and behaviors upon differential thermal analyses were determined for the materials at the various relative humidities. Results obtained indicate that the exchangeable cations are located between the silicate layers of which the mineral is formed. In the magnesium and alkaline-earth salts, the first step of water sorption is the hydration of the cation with six molecules of water which is followed by completion of a water layer having a hexagonal type structure. A second water layer of similar structure is taken up at high relative humidities. Similar results were obtained for the lithium salt except that only three molecules of water were required for the hydration of the lithium ion. In sodium, potassium, and cesium salts the cation apparently was not hydrated. This was also true for the hydrogen ion in the clay acid. The methods used in the work, although inexact, give a clear picture of the sorption process for water which is entirely different from van der Waals' process for the adsorption of gases such as nitrogen. Illustrated. F.G.H.

Hydrothermal reactions. Magnesium hydrosilicates. W. JANDER AND R. FELT. *Z. Anorg. & Allgem. Chem.*, **242** [2] 145–60 (1939).—The synthesis of talc and serpentine was studied up to 600°C. Both compounds were prepared at 300°C. but the reaction velocity was very slow. According to the genesis in nature it is not unreasonable to suppose that the formation is possible at still lower temperatures. In the system MgO–SiO_2–H_2O, from 300° to 600°C. and at higher pressures, these two compounds only appear, and a simple phase diagram results. Between 100 and 60% MgO, $Mg(OH)_2$ and serpentine appear; between 60 and 42% MgO, serpentine and talc exist; and at smaller quantities of MgO, talc and SiO_2 appear. Between 69 and 76% MgO, the humite territory is indicated in the phase diagram by dotted lines. This arises hydrothermally only between 360° and 600°C. when, at times, a certain quantity of fluorine is present. Anthophyllite and meerschaum do not form under these conditions. The above results apply only to high pressures. Using the molar proportions of serpentine at steam pressure, the magnesium orthosilicate forsterite, instead of serpentine, is prepared. This investigation shows a decided temperature-pressure relationship in the formation of the orthosilicate or serpentine so that the equilibrium $2(3MgO \cdot 2SiO_2 \cdot 2H_2O) \rightleftharpoons 3Mg_2SiO_4 + SiO_2 + 2H_2O$ may be determined from the synthetic path. The temperature-pressure curve obeys the Arrhenius equation, i.e., log pressure is inversely proportional to the absolute temperature. The heat of reaction is about 18 Cal. per mole H_2O, a value that is not so accurate but lies in the range of probability. As yet the equilibrium of talc-Mg metasilicate has not been observed. The reaction lies outside the investigated temperature-pressure range. Magnesium orthosilicate can be formed from the components under a steam pressure of 35 kgm. per sq. cm. at 360°C. R.K.

Improve physical properties of clays by controlling pH values. H. G. SCHURECHT. *Brick & Clay Record*, **94** [3] 18–21 (1939).—Practically any clay body may be improved in its physical properties by adjusting the alkalinity or acidity of the raw material. Alkalis, when added to clay bodies, cause deflocculation, and the addition of acids will cause the opposite effect, known as flocculation. The addition of small amounts of alkalis to plastic clays produced remarkable changes in their properties, such as increased dry and fired strengths, greater plasticity, denser bodies, less cracking, less shrinkage, etc. The pH value shows the acidic or basic intensity of a clay. Tests conducted on sewer-pipe bodies with and without soda ash showed that the addition of 0.5% soda ash decreased the absorption of the pipe to a marked extent, while the addition of 1% increased the absorption. The addition of sodium hydroxide, another compound which increases pH values, to graphite-crucible bodies containing Dorset bond clay spoiled the working properties of the bodies; the addition of the same electrolyte to bodies containing Mississippi bond clay improved their moldability. Small additions of sodium hydroxide to bodies containing Dorset clay decreased the dry transverse strength, but where larger percentages were used, the opposite was true. The addition of sodium hydroxide increased the strength of the body containing Mississippi clay. Small amounts of hydrochloric acid made the body containing Dorset clay more open, while larger percentages made the body less porous. Sodium hydroxide made this same body less porous. Small amounts of sodium hydroxide decreased the porosity of the Mississippi clay body, while larger percentages increased it. The difference in behavior of the Dorset and Mississippi bond clays is apparently due to a difference in their initial pH values. A plastic fire clay, a semiplastic fire clay, and a flint fire clay were investigated. The dry strength of these clays was increased greatly by grinding in a wet pan with the addition of 1% sodium hydroxide. The plasticity of all the clays investigated was increased by wet grinding, screening, and the addition of 1% dextrine. The addition of 1% sodium hydroxide caused the clays to become tougher in the plastic condition, but they did not possess as good plasticity for molding. Clays which chemical treatment will not improve

can be determined by a series of tests. The best pH value varies for different clays. According to Barker and Truog (*Jour. Amer. Ceram. Soc.*, **22** [9] 308–12 (1939)) the best pH ranges between 6 and 8.5 for acid clays and between 7.3 and 10.5 for nonacid clays. A chart gives recommendations for the addition of electrolytes in pH control. J.J.H.

Kaolin deposits of Santa Severa. FELICE DE CARLI. *Ind. Mineraria*, No. 9, pp. 372–87 (1939); abstracted in *Centro Studi Ceram. Bibliografia*, **1940**, p. 2.—Geological data on the two deposits of Santa Severa are given. Crystallographical examination of the powder from one of the deposits (Eri) showed that the principal impurity is quartz; chemical analysis showed an alumina content of 19.63%. The plasticity of this kaolin is measured and is compared with that of English kaolin. This kaolin, when refined, can be used in pastes for faience, in the production of grog for refractories, and for filler in paper. Chemical analysis of the crude material from the second deposit (Sassone) showed an alumina content of 16.41% which is increased to 32.64% after washing. After firing, both kaolins had the same geological constitution. These deposits are of great importance. M.V.C.

Laws governing the interaction of clays and soils with electrolytes. I. N. ANTIPOV-KARATAEV, S. P. ONATSKIĬ, AND V. A. CHERNOV. *Trudy Pochvennogo Inst. Dokuchaeva*, **20**, 5–32 (1939); *Chem. Abs.*, **34**, 4844 (1940).—The mass law equation was applied in the study of ion exchange in soils and clays by keeping constant the ionic concentration of the electrolytes. A linear relation between the pH and the magnitude of base exchange was established. Extensive data, in the form of tables and 25 graphs, are presented on the relation of the exchangeable cations H, Li, Sr, Ca, Mg, K, and Na and the stability of soil and clay suspensions. The moisture relationships of the clays, sedimentation, filtration, suction force, and drying properties as affected by electrolytes were extensively investigated.

Length changes of whiteware clays and bodies during initial heating, with supplementary data on mica. R. F. GELLER AND E. N. BUNTING. *Jour. Research Nat. Bur. Standards*, **25** [1] 15–40 (1940); RP 1311.—Length changes of 9 kaolins, 4 ball clays, and 3 whiteware bodies were observed during their initial heating to a maximum temperature of 1250°C. The apparatus used was an especially designed porcelain dilatometer. Differential heating curves for two clays and the specific gravity and weight losses of mica after holding at several temperatures were obtained as supplementary data. Primary kaolins and ball clays show less contraction between 500° and 900°C. than do the secondary kaolins. The contraction (about 3% in a relatively pure clay) and the mica content show a sufficiently close relation to indicate strongly that the mica content, rather than geological history or particle-size distribution, is the predominating factor determining length change in this temperature range. The contraction between 900° and 1000°C. is believed to be caused by the crystallization of amorphous alumina, resulting from the breakdown of the kaolinite molecule, to gamma-alumina. The data show a direct relation between the amount of this contraction and the calculated amount of alumina contributed by kaolinite. The very rapid contraction accompanying vitrification, beginning at about 1050°C. in ball clays and 1100°C. in kaolins, varied from about 6% of the original length for primary kaolins to 12% for a secondary ball kaolin. Particle size appears to be the principal factor determining this contraction. Changes in length of the bodies in the range from room temperature to 1000°C. were gradual, and the maximum change (expansion) was 0.8% of the original length. Above 1000°C. the rate of change (contraction) increased rapidly. The maximum rate noted was 0.3% per min. for a talcose body on a 9-hr. schedule in the temperature range 1135° to 1170°C. Based on unit temperature rise, the maximum length change noted was 0.13% per 1°C. for the same body during a 24-hr. schedule in the temperature range 1100° to 1150°C. In every test of a body (or of an individual clay) the shrinkage per unit temperature rise during the first stages of the final rapid contraction was greater on the 24-hr. schedule than on the 9-hr. schedule. In some cases the shrinkage rate decreased more on the long schedule, during the last 25° to 50° of temperature rise and the first 50° to 100° of cooling, than on the shorter schedule. As a result, the shrinkage during the shorter schedule forged ahead with the result that the total shrinkage during the shorter schedule was greater than that during the longer schedule. R.A.H.

Refractory materials of the Ak-tash deposits. A. S. BAZILEVICH. *Ogneupory*, **8** [1] 53–57 (1940).—Results of the technological study of large deposits of alunite, agalmatolite, kaolinite, and diaspore are discussed. M.V.C.

Serpentinites from Beden, a raw material base for the industry located in South Russia. N. E. EFREMOV. *Ogneupory*, **7** [12] 764–68 (1939).—E. gives a geological and microscopical description of serpentine deposits. These serpentinites can be used as raw material for the manufacture of forsterite refractories. M.V.C.

Silicate minerals: zeolites, their use. V. CHARRIN. *Verre & Silicates Ind.*, **11** [3] 35–36 (1940).—Zeolites may be considered either hydrosilicates of alumina and a protoxide, such as lime, soda, potash, baryta or strontia, or a hydrated feldspar, an unstable transition mineral between feldspar and kaolin (before the alkalis have disappeared). Zeolites are characterized by their great fusibility accompanied by bubbling (the word zeolite is derived from *zein*, to boil, and *lithos*, stone), low density (2 to 2.3), easy cleavage, and weak refractivity and birefringence; it is easily attacked by acids with the production of gelatinous or pulverulent silica and is generally colorless or white. Zeolites can be considered secondary products of a great number of volcanic and eruptive rocks. The varieties of zeolites are distinguished by the degree of hydration of the original feldspar and by the form of their crystals; they include (1) scolecite, $CaO \cdot Al_2O_3 \cdot 3SiO_2 + 3H_2O$; (2) natrolite, $Na_2O \cdot Al_2O_3 \cdot 3SiO_2 + 3H_2O$; (3) analcime, $Na_2O \cdot Al_2O_3 \cdot 3SiO_2 + 2H_2O$; (4) chabasite, $(CaNa_2)O \cdot Al_2O_3 \cdot 4SiO_2 + 6H_2O$; (5) stilbite, $(CaNa_2)O \cdot Al_2O_3 \cdot 6SiO_2 + 2H_2O$; (6) phillipsite, $(CaNa_2K_2)O \cdot Al_2O_3 \cdot 4SiO_2 + 4H_2O$, potassium zeolite; (7) thomsonite, $(CaNa_2)O \cdot Al_2O_3 \cdot 2SiO_2 + 2H_2O$, a variety of chabasite; (8) harmotome, $(K_2Ba)O \cdot Al_2O_3 \cdot 5SiO_2 + H_2O$; (9) heulandite, $CaO \cdot Al_2O_3 \cdot 6SiO_2 + 2H_2O$, a variety of scolecite in which strontia may replace part of the lime; and (10) apophyllite, $(Ca \cdot K_2O) \cdot 6SiO_2 + H_2O$, zeolite without aluminum. Glauconite, though not a zeolite in the strict sense of the term, is sometimes included in the list. Zeolites are better adsorbents than fuller's earth. Artificial zeolites are made by mixing solutions of aluminate of soda and silicate of soda and the addition of other mineral salts; they are always amorphous and are white or gray; they occur in grains of 0.5 to 2 mm. See "Zeolites," *Ceram. Abs.*, **19** [5] 125 (1940). M.V.C.

Stability of silica hydrates of definite composition. R. SPYCHALSKI. *Z. Anorg. & Allgem. Chem.*, **239** [3] 317–20 (1938).—Hydrates of silica free of electrolytes can be prepared by hydrolysis of the ethyl ester of orthosilicic acid ($Si(OC_2H_5)_4$). From the vapor tension-water content isotherm, the following hydrates have been proved to exist: $SiO_2 \cdot 0.5H_2O$, $SiO_2 \cdot 1.0H_2O$, $SiO_2 \cdot 1.5H_2O$, $SiO_2 \cdot 2.0H_2O$, and $SiO_2 \cdot 2.5H_2O$. $SiO_2 \cdot 0.5H_2O$ was found at 15°C. and the others were found at 30°C. The individual hydrates can be prepared without difficulty. The material was investigated when it was 8 and 10 months old. Aging increases the stability of the hydrates. The solubility of the hydrates in water is given in a table; it decreases with increasing water content. W.K.

Study of soils: XXII, Necessity for specifying that which is called "clay." J. CLARENS AND J. LACROIX. *Bull. Soc. Chim., Mem.*, [5] **6**, 979–83 (1939).—The word "clay" is used by the agriculturist in one sense and the mineralogist in another sense. To avoid confusion, the authors propose that "agragile" be used in French literature for "clay" having the agricultural sense and that the regular word "argile" be used for "clay" in the mineralogical sense. D.A.B.

Treatment of leucitic and other aluminous minerals with acids. G. A. BLANC AND F. JOURDAN. *Atti X° congr. intern. chim.*, 1938, **4**, 7–8; *Brit. Chem. & Phys. Abs.–B*, **59** [7] 524 (1940).—Under appropriate conditions, Fe and Si are removed from the liquors by adsorption as hydroxides on the insoluble matter.

BOOKS AND SEPARATE PUBLICATIONS

Beneficiation of Boron Minerals. Metallurgical Division Progress Report No. 40. Beneficiation of Boron Minerals by Flotation as Boric Oxide. R. G. KNICKERBOCKER AND F. K. SHELTON. **Production of Calcium Borate from Colemanite by Carbonic Acid Leach.** R. G. KNICKERBOCKER, A. L. FOX, AND L. A. YERKES. *U. S. Bur. Mines Repts. Investigations*, No. 3525, 18 pp. Free.—The results obtained in these two investigations are given. R.A.H.

Bentonite: Its Properties, Mining, Preparation, and Utilization. C. W. DAVIS AND H. C. VACHER. Revised by JOHN E. CONLEY. *U. S. Bur. Mines Tech. Paper*, No. 609, 83 pp. Govt. Printing Office, Washington, D. C. Price 15¢.—This revision of *Tech. Paper* No. 438 covers an investigation undertaken to add to the general information on the properties and uses of bentonite. It includes a brief compilation of the geologic and geographic occurrences, a study and discussion of different samples of bentonite-like material, and a compilation of the known and suggested uses, including a list of the U. S. patent literature. R.A.H.

Charts for the Analysis of Minerals by X-rays (Nomogramme zum Mineral Bestimmen mit Röntgenstrahlen). M. MEHMEL. Verlag der Deutschen Mineralogischer Gesellschaft e.V. through the Verlagbuchhandlung Gustav Fischer, Jena, 1939. Reviewed in *Jour. Amer. Chem. Soc.*, **62** [2] 459 (1940).—The identification of crystalline compounds by means of their X-ray powder diffraction patterns has potential possibilities which have not yet been fully utilized. The recent tables of Hanawalt, Rinn, and Frevel (*Ind. Eng. Chem., Anal. Ed.*, **10**, 475 (1938)), giving the spacings and relative intensities for 1000 compounds, represent the first big step toward making X-ray identification a practical working method. M.'s charts are essentially supplementary to data such as those given in the Hanawalt tables. The charts give the diffraction diagrams for 17 minerals of interest in sedimentary petrography (quartz, calcite, clays, feldspar, etc.). Each pattern is represented by a series of vertical lines, the height of a line giving the intensity and the lines being plotted against log sin θ as abscissa. For each mineral there are three charts corresponding to Cu, Fe, and Cr radiation. As the charts give a direct picture of the diffraction pattern, they are a useful supplement to tabulated spacing data. F.G.H.

Chromite. ROBERT H. RIDGWAY. Preprint from U. S. Bur. Mines Minerals Yearbook, 1940. 14 pp. Govt. Printing Office, Washington, D. C. Price 5¢. R.A.H.

Clay Investigations in the Southern States, 1934–1935. W. B. LANG, P. B. KING, M. N. BRAMLETTE, T. N. MCVAY, H. X. BAY, AND A. C. MUNYAN, with an introduction by G. R. MANSFIELD. *U. S. Geol. Survey Bull.*, No. 901, 346 pp. Govt. Printing Office, Washington, D. C. Price $1.00.—This publication contains a group of reports covering investigations in S. C., Ga., Fla., Ky., Tenn., Ala., Miss., and Texas. In S. C., Ky., Tenn., Ala., and Texas both ceramic and bleaching clays were studied, but in the other states only bleaching clays were studied. In South Carolina no bleaching clays of commercial interest were found, but clays giving promise for use in the rubber and whiteware industries were studied. In Georgia, clays both naturally active and activable were investigated. Some of these proved to be of high quality and deserving of further study. Florida, like Georgia, known for its fuller's earth, was found to have hitherto unsuspected but apparently large deposits of high-grade activable clays which may prove to be a new commercial asset for the State. Kentucky and Tennessee apparently have large supplies of low-grade bleaching clays, but these are less accessible to markets than similar clays now marketed in Illinois. Some of the ball clays sampled in Tennessee are of value for particular uses and may be worth developing. Results of bleaching clay investigations in Alabama were generally disappointing, though some material worthy of further study was found. Many localities throughout the State were examined for possible supplies of ceramic clay. Those of greatest promise were prospected and tested. Activable bleaching clays of considerable extent and promise were found in Mississippi. In Texas bleaching clays of both naturally active and activable types were investigated. None of high quality was found; this was also true of ceramic clays. R.A.H.

Feldspar. ROBERT W. METCALF. Preprint from U. S. Bur. Mines Minerals Yearbook, 1940. 10 pp. Govt. Printing Office, Washington, D. C. Price 5¢. R.A.H.

Geology of North America: Vol. I, Introductory Chapters and Geology of the Stable Areas. Gebrüder Borntraeger, Berlin-Zehlendorf, 1939. In English. 643 pp., 14 plates, 53 figs. Price, cloth, 16 Rm.—Reviewed in *Bull. Amer. Assn. Petroleum Geologists*, **24** [6] 1134–35 (1940). G.M.H.

Microscopic Determination of the Ore Minerals. M. N. SHORT. *U. S. Geol. Survey Bull.*, No. 914, 314 pp. Govt. Printing Office, Washington, D. C. Price $1.00.—S. gives detailed information regarding the means of preparing the opaque minerals for study, useful equipment, and methods of identification. The main topics considered are microscopic technique, grinding and polishing, abrasives, measurements of reflectivity, spectrographic methods, etch reactions, microchemical methods, and determinative tables. The many advances which have been made are described. R.A.H.

Mining of Feldspar and Associated Minerals in the Southern Black Hills of South Dakota. J. R. GUITERAS. *U. S. Bur. Mines Information Circ.*, No. 7112, 104 pp.—G. describes the mining of pegmatite minerals, from the standpoint of the feldspar industry, from the pegmatite dikes of the southern Black Hills. R.A.H.

More Jobs for Minerals. PAUL M. TYLER. *U. S. Bur. Mines Information Circ.*, No. 7118, 19 pp. Free.—T. describes the growing use of minerals, the increasing variety of raw materials, the place of minerals in modern industry, the new uses for some of the minerals, the competition of minerals with one another, how markets are found for them, and the minerals that are "looking for new jobs." R.A.H.

Ore-Testing Studies: II. Metallurgical Division Progress Report No. 39. EDMUND S. LEAVER, JESSE A. WOOLF, AND A. P. TOWNE. *U. S. Bur. Mines Repts. Investigations*, No. 3515, 76 pp. Free.—Precious metals are dealt with. See *Ceram. Abs.*, **19** [6] 148 (1940). R.A.H.

Pinite; New Refractory. ANON. *U. S. Bur. Mines Mineral Trade Notes*, **9** [5] 23 pp. (1939). Free.—A brief description is given of this mineral which is found near Oreana, Nev. R.A.H.

Potash Situation. BERTRAND L. JOHNSON. *U. S. Bur. Mines Information Circ.*, No. 7117, 6 pp. Free.—J. reviews post-war changes in the international situation, the rise of a domestic industry, 1939 developments, former German markets for potash, and opportunities for non-German exporters. R.A.H.

Preliminary Report on Brucite Deposits in Ontario and Quebec and Their Commercial Possibilities. M. F. GOUDGE. *Can. Dept. Mines, Bur. Mines, Mines & Geol. Branch, Dept. Mines & Resources, Memorandum Series*, No. 75 (Dec., 1939). 57 pp., 3 maps, 2 plates.—Brucite of commercial importance occurs in pre-Cambrian limestones of the Rutherglen, Ont., and Wakefield and Bryson, Quebec, areas. A process has been devised for the recovery of granular brucite by calcination followed by hydration, screening, and washing, the lime being hydrated while the calcined brucite retains its natural granular form. In this way a highly pure magnesia can be obtained (from a brucitic limestone containing 25% or more brucite) at an estimated gross cost of not more than $30 per ton; at this price it could easily compete with imported magnesia in eastern Canada. This magnesia is highly

suitable for the manufacture of basic refractories, magnesium metal, and various magnesium salts and for other uses of magnesia. The possibilities of other methods of recovery are studied. G.M.H.

Staining of Clay Minerals as a Rapid Means of Identification in Natural and Beneficiated Products. GEORGE T. FAUST. *U. S. Bur. Mines Repts. Investigations*, No. 3522, 21 pp. Free.—F. describes staining technique, artificial pleochroism of clay minerals, special problems in dealing with bentonites, and the detection of clay minerals in natural and beneficiated products. R.A.H.

Talc, Pyrophyllite, and Ground Soapstone. BERTRAND L. JOHNSON AND K. G. WARNER. Preprint from U. S. Bur. Mines Minerals Yearbook, 1940. 11 pp. Govt. Printing Office, Washington, D. C. Price 5¢. R.A.H.

PATENTS

Producing materials of magnesium silicate for ceramic purposes. STEATIT-MAGNESIA A.-G. Ger. 689,029, Feb. 15, 1940 (July 14, 1936); VI/80*b*. 8.08.—Magnesium silicate materials with a low iron content for ceramic purposes are produced from naturally occurring magnesium silicate raw materials with an iron oxide content, having a bright red color. The raw material, after being finely ground, is melted down in an arc furnace, and the resulting fused charge is ground up again, subjected to an ordinary magnetic separation of impurities, washed, and finally prepared by adding a known inorganic and/or organic material to the mass which does not influence the firing color; the plasticity required for ordinary ceramic operations is maintained. D.A.B.

Production of beryllium compounds which are free from fluorine. I. G. FARBENINDUSTRIE AKT.-GES. Brit. 524,171 and 524,321, Aug. 14, 1940 (April 5, 1938).

Treating clays. WISCONSIN ALUMNI RESEARCH FOUNDATION. Brit. 524,487, Aug. 21, 1940 (April 6, 1938).

Treatment of china or other clays or clay substances for the removal of objectionable coloring matter contained therein. GOONVEAN & ROSTOWRACK CHINA CLAY CO., LTD., AND L. E. B. PEARSE. Brit. 524,074, Aug. 14, 1940 (Nov. 14, 1939).

Chemistry and Physics

Accelerated method of quartzite analysis. N. O. ZELDIN. *Ogneupory*, **7** [8] 560–64 (1939).—The method is based on the evaporation of quartzites in hydrofluoric acid in the presence of oxalic acid. Details are given of the determination of SiO_2, R_2O_3, Fe_2O_3, TiO_2, and Al_2O_3. M.V.C.

α to β transformation of quartz. C. V. RAMAN AND T. M. K. NEDUNGADI. *Nature*, **145** [3665] 147 (1940).—The authors present spectra of monochromatic light (4358 a.u. radiation of Hg arc) scattered in a quartz crystal at seven different temperatures ranging from that of liquid air (−192°C.) to +530°C. A fully exposed spectrum at room temperature indicates 14 different normal modes of vibration of the crystal. At −192°C., the three most intense lines correspond to the frequency shifts 132, 220, and 468 cm.$^{-1}$, and all are equally sharp. Changes occur as the crystal is heated. The 220-cm.$^{-1}$ line spreads out toward the exciting line and becomes a weak diffuse band as the transition temperature is approached. The other intense lines having both larger and smaller frequency shifts continue to be easily visible, though appreciably broadened and displaced. This behavior of the 220-cm.$^{-1}$ line indicates that the binding forces which determine the frequency of the corresponding mode of vibration of the crystal lattice diminish rapidly with rising temperature. The authors infer that the increasing excitation of this particular mode of vibration with rising temperature and the deformation of the atomic arrangement resulting are in a special measure responsible for the progressive changes in properties occurring in the crystal over the range 200° to 575°C. as well as for inducing the transformation from the α to the β form. Illustrated. J.L.G.

Aluminum silicofluoride, its preparation in the solid state, and its properties. A. A. SANFOURCHE AND A. KRAPIVINE. *Bull. Soc. Chim., Mem.*, [5]**6**, 1689–96 (1939).—Aluminum silicofluoride or aluminum fluosilicate was obtained in solution by Sainte-Claire Deville; he was not successful in isolating it in the solid state because of the instability of its solution. Amorphous substances have been described under this name whose composition was not indicated or which did not respond like the true substance; the authors believe them to have been merely decomposition products of the solution. They succeeded in crystallizing this substance from concentrated solutions under very definite conditions; this permitted the identification and study of its properties, one of which is hydrolysis. D.A.B.

Colorimetric determination of copper with triethanolamine. JOHN H. YOE AND CHARLES J. BARTON. *Ind. Eng. Chem., Anal. Ed.*, **12** [8] 456–59 (1940).—A spectrophotometric investigation of the colorimetric determination of copper with triethanolamine included a study of the effect of concentration of the reagent and of the effect of ammonium, sodium, and potassium salts on the transmission of copper-triethanolamine solutions and a test of the conformity to Beer's law, at several concentrations, of triethanolamine. A comparative study of the ammonia method was also made. There is little difference in the sensitivities of the copper-ammonia and copper-triethanolamine methods, although the latter is slightly more sensitive at low concentrations of copper. Illustrated. F.G.H.

Colorimetric determination of iron with salicylaldoxime: a spectrophotometric study. D. E. HOWE WITH M. G. MELLON. *Ind. Eng. Chem., Anal. Ed.*, **12** [8] 448–50 (1940).—A spectrophotometric study of the complex formed by the action of ferric iron on salicylaldoxime has indicated that this complex might be used for the colorimetric determination of ferric iron. The complex is most suitably used for this purpose in a neutral solution, pH being a critical factor in the determination. The range of concentrations is from 0.05 to 10 p.p.m. of iron, with the limits being extended each way by proper dilution or concentration. Interfering substances are easily removed, the reagent is highly specific, and no special techniques are necessary. Salicylaldoxime is recommended as a reagent for the colorimetric identification and determination of small amounts of ferric iron. Illustrated. F.G.H.

Effect of ultrasonic waves (U.S.W.) on colloidal phenomena: V, Influence on thixotropy: II, Thixotropic systems of ferric hydroxide. N. SATA AND N. NARUSE. *Kolloid Z.*, **89**, 341–44 (1939).—In considering the action of ultrasonic waves upon thixotropy, attention is called to some important factors which, besides aggregation and hydration, cause an orientation of the particles. One of these factors is that most of the thixotropic systems contain nonspherical particles. For Part I see *Ceram. Abs.*, **19** [7] 175 (1940). L.E.T.

Equilibrium measurements on sodium silicates. E. ZINTL AND H. LEVERKUS. *Z. Anorg. & Allgem. Chem.*, **243** [1] 1–13 (1939).—No additional compounds could be formed from Na_2SiO_3 and NaOH or NaF up to temperatures as high as 500°C. An apparatus is described for the measurement of steam pressures and for the completion of isothermal decomposition by dehydration equilibria. The equilibrium pressures of the following reactions can be measured (and reproduced) between 350° and 500°C.

$$Na_2SiO_3 + 2NaOH \rightleftharpoons Na_4SiO_4 + H_2O \quad (1)$$
$$2Na_2SiO_3 + 2NaOH \rightleftharpoons Na_6Si_2O_7 + H_2O \quad (2)$$
$$Na_6Si_2O_7 + 2NaOH \rightleftharpoons 2Na_4SiO_4 + H_2O \quad (3)$$

All three reaction curves intersect at 402°C. and 240 mm. Hg. According to thermodynamic demands, the tension of 1 is the geometric mean of 2 and 3. Through isothermal decomposition below and above 402°C. and through X-ray diagrams, the coordination of the tension curves with the equilibriums 1 to 3 was ascertained. The three reac-

tions are isothermic from right to left with heats of reaction of 12.0, 18.0, and 5.8 Cal. Sodium pyrosilicate is unstable below 402°C. and breaks down into the orthosilicate and metasilicate. The heat of reaction for this decomposition is 12.2 Cal. The dependence of the stable products from the reaction of Na_2SiO_3 and NaOH on the proportions, temperature, and steam pressure between 350° and 500°C. was investigated. R.K.

London-van der Waals force between two disk-shaped particles. G. P. Dube and H. K. Das Gupta. *Compt. Rend.*, **209** [6] 340–42 (1939).—Systems showing the phenomenon of thixotropy are built up in general of nonspherical particles, e.g., the particles of iron oxide are disk-shaped. The formula for the interaction of two particles is developed for the cases where (1) the disks are in the same plane, and (2) the planes are parallel and perpendicular at their centers; the energy E is then given by $E = -9^2\lambda\delta l_1\delta l_2\int_{S_1}\int_{S_2}\frac{dS_1dS_2}{v^6}$, where λ = the London-van der Waals constant, δl_1 and δl_2 = the thicknesses of the two disks, dS_1 and dS_2 = surface elements, v = the distance between the elements, and 9 = the number of atoms per cm.³. The evaluation of the integrals shows that the force in case 1 is greater than that in case 2; the force is also different from that of the spherical particles. In thixotropic pastes, the particles are arranged preferably according to case 1. M.H.

Mechanism of the aggregation of silicic acid from sodium-silicate solution: I, Low molecular silicic acid stable in acid solution. A. Riad Tourky. *Z. Anorg. & Allgem. Chem.*, **240** [2] 198–208 (1939).—The equilibrium between low and higher molecular silicic acid in diluted sodium silicate solution was investigated in regard to its relationship to pH, age, and kind of acid. Diluted solutions of sodium metasilicate were ultrafiltrated after the addition of varying amounts of acids. A table gives the pH, age of the solution in days, duration of the filtration in minutes, and the amount of silica retained on the filter. Silica begins to precipitate in colloidal form at pH 10.85, and the amount reaches a maximum at the point of neutralization, pH 6.8. At pH 2.8 only 8% is colloidal after one day. At lower pH values the amount rises again. The cause of the stability of the low molecular silicic acid at pH 2.8 was investigated. The low molecular, acid soluble silica is not formed through solution of the precipitated silica but is a stabilized form of the silica in alkaline solution. Not only the pH value but also the nature of the acid influences the stabilization; phosphoric acid has the greatest influence and nitric acid the least. The acids form intermediate compounds with the silicic acid which decompose later on. For the silicate-HCl solution this fact was further demonstrated by potentiometric and conductometric observations. **II, Structural observations.** *Ibid.*, [3] 209–16.—Silicic acid precipitates in two distinct forms: from the ultrafiltrated diluted acid solutions in the form of fibers and from the alkaline ultrafiltrates and the concentrated solutions as flocks. The formation of flocks cannot be due to quick polymerization. With the use of a dilatometer it was proved that a difference exists between the precipitates from concentrated acid and alkaline solutions. The precipitate from acid solutions shows an increase in volume at the time of flocculation which must be attributed to a release of water during the formation of the fibrillose structure, i.e., of oxygen bridges. Since the fibrils appear only where the acid acts as stabilizer, the formation of intermediate acid-silica compounds is further confirmed. Upon the breaking up of these intermediates, active silica is set free which is capable of forming chains. W.K.

New types of electrodes for potentiometric and conductometric titrations. Hidehiro Goto. *Science Repts. Tôhoku Imp. Univ., Series 1*, **29**, 9–21 (1940).—For potentiometric titrations four different types were developed: (1) A Jena glass microfiltering tube has a small tube attached; an electrolyte is put in and a Pt wire coated with Pt black is inserted. The electrolyte does not flow through the pores of the tube. (2) Ground glass was put in the end of a glass tube and heated until it sintered. This is similar to type 1. (3) A tube was made with a small ground glass stopper in the lower end. The electrolyte was put in, the plug loosened momentarily, and seated firmly. (4) A small stop cock in the end may be similarly used. It is totally immersed. Tests were made on neutralization, permanganate, iodine, bromate, dichromate, and precipitation titrations. They all gave sharp breaks at the end point. Platinum-plated and gold-plated glass electrodes were developed for conductometric titrations. These gave sharp breaks in aqueous solutions and with small amounts of organic solvents; they could be used with higher amounts of solvents, but the break was not as sharp. W.D.F.

Oxide determination in clays and grog products. A. I. Lobanov. *Ogneupory*, **7** [10–11] 712–14 (1939).—The determination is based on the precipitation of oxides of aluminum, iron, and titanium by means of alkalis or ammonia without preliminary separation of silica. Details are discussed. M.V.C.

Process of mullitization of refractory clays from Latninskil and Chasov-Yar deposits. A. K. Freberg. *Ogneupory*, **7** [12] 758–64 (1939).—The consecutive crystallization of mullite crystals in the clays studied was determined. Up to 1200° a reaction takes place during the formation of mullite from the products of the dissociation of kaolin (alpha-alumina and silica). Above this temperature the mullite crystals grow in size. F. determined the dependence of the growth of mullite crystals on temperature and time in the firing interval between 1200° and 1400°. This dependence can be checked for other ceramic products, particularly for those made of silica and magnesite. With slow cooling, recrystallization of mullite out of the melt occurs, e.g., samples of Latninskil clays cooled very rapidly from 1550° contained 7% less mullite (undissolved in hydrofluoric acid) than those cooled slowly. Mullitization is not the only factor affecting physicochemical properties of the products; the composition and amount of the glass phase and the "overcrystallization" of silica are also of great importance. There are definite temperature intervals for porosity, shrinkage, and brittleness at which these indices have an optimum significance; this conclusion should be checked with grog products having different thermal treatment and a different granulometric composition. See "Firing...," *Ceram. Abs.*, **19** [6] 147 (1940). M.V.C.

Reaction behavior of various SiO_2 modifications. C. Kröger and W. Graeser. *Z. Anorg. & Allgem. Chem.*, **242** [4] 393–405 (1939).—The action of cristobalite on lithium, calcium, and sodium-calcium carbonates was investigated. Lithium carbonate forms the unstable equilibrium, $Li_2CO_3 + SiO_2 \rightleftharpoons Li_2SiO_3 + CO_2$. $CaCO_3$ forms a solid solution with cristobalite. The action of $Na_2Ca(CO_3)_2$ is as follows: $3Na_2Ca(CO_3)_2 + SiO_2 \rightarrow Na_2O\cdot 2CaO\cdot 3SiO_2 + 2Na_2O\cdot CaO\cdot 3SiO_2 + 6CO_2$. The action of cristobalite, tridymite, and precipitated silica on K_2CO_3 was also investigated. The reaction of SiO_2 with K_2CO_3 forms initially a solid solution from which the reaction product, $K_2Si_2O_5$, must crystallize. R.K.

Silicides of calcium. V. Louis and H. H. Franck. *Z. Anorg. & Allgem. Chem.*, **242** [2] 117–27 (1939).—After the accurate fixation of the preparation conditions for calcium monosilicide, the authors were able to produce a compound whose purity was hitherto unattainable (98%). Debeye-Scherrer diagrams indicated the presence of two monosilicides. The conditions under which they are formed and mutually transformed are presented. The conversion of the monosilicide into the stable disilicide was thoroughly investigated. The first completed preparation and investigation of the dicalcium monosilicide permitted the series of calcium silicides to become enriched with a further member. The crystal structure of this compound can be extensively clarified. The Debeye-Scherrer diagrams of the pure compounds and their mixtures show the errors of mutual solubility in the system Ca–Si. R.K.

Specific heats at low temperatures of tantalum oxide and tantalum carbide. K. K. Kelley. *Jour. Amer. Chem. Soc.*, **62** [4] 818–19 (1940).—Specific heat measurements of tantalum oxide and tantalum carbide were made in the

temperature range 53° to 298.1°K. The entropies are $S_{298.1} = 34.2 \pm 0.4$ for tantalum oxide and $S_{298.1} = 10.1 \pm 0.1$ for tantalum carbide. The free energy of formation of tantalum oxide from the elements has been computed as $\Delta F^{\circ}_{298.1}$ −453,700. Illustrated. F.G.H.

Synthesis of some minerals of the spinel group. N. L. Dilaktorskiĭ. *Zapiski Vserossiĭskogo Mineral. Obshchestva*, **68** [1] 18–26 (1939); *Khim. Referat. Zhur.*, **1939**, No. 8, p. 20; *Chem. Abs.*, **34**, 5018 (1940).—The synthesis was performed by heating the oxides in an atmosphere of dry HCl and by the firing method. The latter method was used for the synthesis of Ni spinels for which the first method could not be applied. Their specific gravities and n were determined. The following spinels were synthesized: (1) picrochromite, $MgCr_2O_4$, a light-green powder, density 4.39, n_D 2.08 ± 0.02, hardness considerably greater than 5; (2) spinel having the composition $Mg(Fe,Cr)_2O_4$, fine-grained, red-brown, n_{Li} 2.22 ± 0.04 (the theoretically calculated n_{Li} 2.215); (3) Ni spinel, $NiAl_2O_4$, light-blue, n_D 1.875 ± 0.015, density 4.45; (4) nickel chromite, $NiCr_2O_4$, a dark-green, nearly black powder, n_{Li} 2.29 ± 0.01, density 5.16 (the compound has not been previously synthesized); (5) trevorite, $NiFe_2O_4$, a dark substance with a reddish violet shade, n 2.69 ± 0.03, density 5.34, hardness greater than 5. A review of all known minerals of the spinel group, the relation between the composition and the physical properties (n and density) of the minerals, and a short description of the methods for the synthesis of spinels are given.

System alkali oxides–CaO–Al_2O_3–SiO_2–CO_2: VIII, Reaction pressures of quartz and disilicates with alkali double carbonates. C. Kröger and K. W. Illner. *Z. Anorg. & Allgem. Chem.*, **241** [4] 338–48 (1939).—The conversion of quartz in the quaternary system $Alk_2^{I}O$–$Alk_2^{II}O$–SiO_2–CO_2 leads to the same reaction pressure as that in the system Alk_2O–SiO_2–CO_2. Because of the better diffusion practicability, the initial pressure of the unstable metasilicate is also observed. The reaction is $Alk_2CO_3 + SiO_2 \rightleftarrows Alk_2SiO_3$ (solid solution) $+ CO_2$. A stable equilibrium between quartz and disilicate does not lie in the quaternary system. The disilicate transformation leads to the same equilibrium pressure in the quaternary system as it does in the ternary system. That which is in the quaternary system of a previous lower eutectic does not influence the pressure values. No noteworthy acceleration of the reaction was obtained. For Part VII see *Ceram. Abs.*, 19 [10] 245 (1940). R.K. + W.K.

Systems MnO–TiO_2 and MnO–FeO–TiO_2. J. Grieve and J. White. *Jour. Roy. Tech. Coll.* [Glasgow], **4**, 660–70 (1940); *Chem. Abs.*, **34**, 4974 (1940).—From thermal, microscopic, and X-ray studies, thermal equilibrium diagrams were constructed for the systems MnO–TiO_2 and MnO–FeO–TiO_2. In the system MnO–TiO_2 two compounds occur, $MnO \cdot TiO_2$ (manganous metatitanate) and $2MnO \cdot TiO_2$ (manganous orthotitanate), the first-mentioned compound melting incongruently. The liquidus curve at the TiO_2 side of the diagram is of the "S" type (as is also probably the case in the FeO–TiO_2 system). The system MnO–FeO–TiO_2 is ternary only if the effects of the peritectic dissociation of FeO (partial liberation at 1370° of metallic Fe with formation of a liquid oxide phase containing approximately 11.5% Fe_2O_3) are neglected. Continuous series of solid solutions are formed between $2MnO \cdot TiO_2$ and $2FeO \cdot TiO_2$ and between $MnO \cdot TiO_2$ and $FeO \cdot TiO_2$; MnO and FeO are also soluble in each other to a considerable extent. Twenty-one photomicrographs of the two systems are included.

X-ray investigation of the system Cr_2O_3–NiO. L. Thomassen. *Jour. Amer. Chem. Soc.*, **62** [5] 1134–36 (1940).—In the equilibrium diagram Cr_2O_3–NiO the spinel $NiO \cdot Cr_2O_3$ is the only compound present. At 1000°C. the solubility of nickel and chromium oxide in the spinel is small. Nickel oxide does not dissolve chromium oxide. F.G.H.

BOOK AND SEPARATE PUBLICATION

International Annual Tables of Constants and Numerical Data (Tables Annuelles Internationales de Constantes et Données Numériques): **Vol. XI (1931–1934), Part I, Sections 1–25.** Hermann and Cie, Paris; McGraw-Hill Book Co., Inc., New York. 519 pp. Price $10.00. Reviewed in *Mech. Eng.*, **62** [9] 691 (1940).—These tables supply periodically new numerical data, physical, chemical, and technological. They are intended for those who make use of quantitative values of the properties of substances and magnitudes that occur in chemical, physical, or technical phenomena and provide a comprehensive digest which will obviate the necessity of searching periodicals. This volume covers the data upon certain subjects which appeared during the years 1931 to 1934. A complete bibliography is included. For Vol. X see *Ceram. Abs.*, **16** [1] 46 (1937). F.G.H.

Quantitative Analysis by X-ray Diffraction: I, Determination of Quartz. James W. Ballard, H. I. Oshry, and H. H. Schrenk. *U. S. Bur. Mines Repts. Investigations*, No. 3520, 10 pp. Free.—The quantitative determination of quartz by X-ray diffraction is considered particularly applicable to industrial-hygiene studies. Methods for determining free silica are described. The principles of the X-ray diffraction method, the apparatus used, the analytical procedure, and the results of tests are also discussed. R.A.H.

PATENTS

Ceramic compositions. Monsanto Chemical Co. Brit. 524,513, Aug. 21, 1940 (Feb. 1, 1938).

Manufacture of alkali-earth carbonates. Kurt Schneider. U. S. 2,211,796, Aug. 20, 1940 (Dec. 3, 1937).—(1) The process of making calcium carbonate of fine particle size comprises causing milk of lime to react with a separately prepared water solution of carbonic acid. (7) The process of making calcium carbonate of fine particle size comprises causing milk of lime to react with a separately prepared saturated water solution of carbonic acid containing an excess of liquid carbon dioxide.

Manufacture of silica gel. Anglo-Iranian Oil Co., Ltd., H. F. Dare, and A. Millien. Brit. 524,142, Aug. 14, 1940 (Dec. 17, 1938).

Manufacture of titanium dioxide pigments. F. L. Kingsbury and C. L. Schmidt (National Lead Co.). U. S. 2,211,828, Aug. 20, 1940 (Oct. 9, 1937).—In a method for preparing titanium dioxide pigments which includes the hydrolytic precipitation of hydrous titanium oxide from a sulfuric acid solution of a titanium compound, the step consists in heating a sulfuric acid solution of a titanium compound containing in solution a compound containing one or more elements selected from the group consisting of the rare-earth elements, cerium, yttrium, and lanthanum, in an amount between about 0.02 and 0.5% calculated as the oxide of the element and based upon the titanium dioxide (TiO_2) content of the titanium sulfate solution hydrolytically to precipitate therefrom hydrous titanium oxide.

Process and apparatus for the production of compositions of lead and its oxides and compositions of related products. C. F. Haunz (Richardson Co.). U. S. 2,211,775, Aug. 20, 1940 (May 15, 1937).—A process of producing a composition of lead and its oxides comprises melting the lead and treating the liquid lead to bring it into a fine filamentary form while still in a metallic condition, thereupon treating the lead with water and evaporating the water therefrom to produce upon the surfaces of the filamentary lead a coating sufficient to prevent coalescence during a milling operation, and thereafter converting a portion of the lead into an oxide by milling the treated filamentary material dry in the presence of an oxidizing atmosphere.

Producing dehydrated borax by gradual heating of crystalline borax. GEBR. BORCHERS A.-G. AND FRIEDRICH BORCHERS. Ger. 680,180, Aug. 3, 1939 (Dec. 30, 1937); IV*b*/12*i*. 40.—Crystalline borax in saturated solution is first heated at a moderate temperature to reduce the water of crystallization from 4 to $2H_2O$. This preliminary dehydrated salt is removed and is completely dehydrated at a higher temperature. D.A.B.

Producing waterproof materials consisting essentially of water glass. MICHAEL GROSKOPF. Ger. 688,575, Feb. 8, 1940 (Dec. 23, 1938); VI/80*b*. 1.03. Addition to Ger. 636,054.—Solutions of metal acetates and metal fluorides are gradually added in any order to water glass. D.A.B.

General

Age and the lead content of certain human bones: a compilation and statistical analysis of recently published data. H. P. MORRIS. *Jour. Ind. Hyg. & Toxicol.*, **22** [3] 101–103 (1940).—There is a significant increase with age in the lead content of four different human bones from different subjects when it is expressed as mgm. lead per kgm. fresh bone. The increase is less marked in the rib and vertebra than in the femur and tibia. The increase in lead was 0.810 mgm. per kgm. of fresh bone per year in the femur, 0.060 mgm. for the rib, and 0.044 mgm. for the vertebra. E.J.V.

Air sampling of asbestos dust. J. W. FEHNEL. *Ind. Med., Ind. Hyg. Sect.*, **9**, 5–7 (Jan., 1940).—For the past 10 years the industrial health section of the Metropolitan Life Insurance Company has been studying the effect of inhalation of asbestos dust upon employees in plants in the United States and the Province of Quebec. The electrostatic dust collector recently placed on the market combines ionization and electric precipitation in entrapping dust, and it is highly effective in securing fine dusts and fumes. The detailed procedure is given for applying both the electrostatic and impinger methods; the results are tabulated in parallel columns. F. concludes, from his study of asbestos dust samples collected in asbestos textile mills, that (1) the impinger and electrostatic methods of sampling agree in the determination of total dust concentration, and (2) the electroprecipitator entraps more fibers than the impinger. Whether this increase has hygienic significance has not yet been determined. Six recent and extensive references are listed. K.R.

Clay products feel preparedness program. JAMES M. LANGE. *Ind. Marketing*, **25** [8] 74 (1940).—Refractories are so essential to armament industries that war has caused a scarcity of some types in England. With American steel production greatly increased, sales of firebrick are considerably higher. Structural clay products are widely used for military construction work such as airports, army barracks, hospitals, warehouses, bomb-proof structures, etc., and will be used on a still larger scale when conscription becomes effective. F.E.S.

Detoxication mechanism: I, Ability of the apple or its constituents to counteract the toxic effects of lead and arsenic. IRA A. MANVILLE, FRANCIS J. REITHEL, PAUL M. YAMADA, T. W. SPENCER, AND JOHN R. RICHARDSON. *Jour. Ind. Hyg. & Toxicol.*, **22** [1] 36–47 (1940).—Rats, guinea pigs, and rabbits were fed diets low in uronic acid. With the exception of the rats' diet, the food mixtures were low in calcium and phosphorus. The animals were fed lead, separate from the diet, in amounts of 47, 19.6, and 6.4 mgm. per kgm. of body weight. Apple supplements were fed to Group A animals in amounts of 35, 49, and 18.3 mgm. per kgm. of body weight; the ratio of lead to apple was 0.74 for the rats, 2.5 for the guinea pigs, and 3.0 for the rabbits. In no instance did the duration of the feeding last over 33 days, 8 days, or 26 days, respectively. The animals receiving the highest proportion of apple (rabbits) showed no signs of toxicity and there was 100% survival. As the amount of apple decreased, the protection afforded was still evident but less marked. It is concluded that the apple is capable of affording protection against the toxic effects of lead. E.J.V.

Exhibition of ceramic machines and kilns. LIP. *Tonind.-Ztg.*, **62** [103–104] 1152–59 (1938).—L. gives a review of an exhibition of ceramic machines and kiln construction. W.K.

Factory dust control. P. C. ZIEMKE. *Mill & Factory*, **25** [3] 73–75, 98, 100 (1939). D.A.B.

Industrial nurse. J. H. CHIVERS. *Ind. Med.*, **9**, 29–31 (Jan., 1940).—In a large industry the industrial nurse is part of a well-organized and functioning medical department. Certain laboratory examinations may be at times required of her: the blood picture, urine examination, or operation of an X-ray unit. Her skill and tact frequently bring about a more stable employer-employee relation. The visiting nurse works in cooperation with the medical director of the company and also with the family doctor. Where employers require an employee to notify the management of his absence from work, with reasons, the visiting nurse is sent at once to ascertain actual conditions, attend to the worker's needs, and report back promptly to the company. K.R.

Industrial nurse as a teacher of nutrition. LEONA PAZOUREK. *Ind. Med.*, **9**, 240–43 (May, 1940).—The industrial nurse can prepare herself to deal with undesirable conditions by (1) taking a nutrition course in a recognized school or college, (2) the study of authoritative books (list given) if unable to take such a course, and (3) the study of pamphlets issued by various Government agencies on the food needs of workers and their food-purchasing habits. P. presents desirable diets and their relative cost, discusses foods containing vitamins, and lists low cost foods with high food values. Suggestions are made for improving the food values in cafeterias which serve employees. K.R.

Industrial workers of 1960. C. P. MCCORD. *Ind. Med.*, **9** [4] 173–78 (1940).—According to present population trends in the U. S., where now one person in every five is over 50 years of age, by 1960, one in every three will exceed that age. The number of young persons under 20 in 1960 will have diminished between one-third and one-half of the present youthful population. Even now there are 1,800,000 fewer children under 10 years of age than there were 15 years ago. Industry, while competing actively for the services of youth in its distinctly decreased numbers, will depend more and more upon available and experienced workers. Cheering statistics are cited from a survey of workers over 40, conducted by the National Association of Manufacturers, involving 2485 questionnaires and 1,656,565 workers, which all but negative the supposed superiority of the youthful member of industry. Sixty per cent of the employers find employees over 40 worth preference, 83% report the sickness rate lower among the older persons and their efficiency rate higher, 81% report their accident risk lowered, and 66% consider the power of adjustment the same as or higher than that shown by younger persons. K.R.

Large and small plants have a health job to do. H. C. BEAVER. *Factory Management & Maintenance*, **98** [2] 72–73 (1940).—B. surveys the field of employee health service in both large and small plants. He considers the management's responsibilities and some of the rewards to be gained. J.L.G.

Percentage of particles of different sizes removed from dust-laden air by breathing. A. M. VAN WIJK AND H. S. PATTERSON. *Jour. Ind. Hyg. & Toxicol.*, **22** [1] 31–35 (1940).—An apparatus was devised, using two thermal precipitators, for measuring the percentage of siliceous dust particles, of different size ranges, removed from dust-laden air by breathing. About 25% of particles of the size 0.2 μ and about 80% of the size 2 μ are removed. Between these two sizes the percentage removal is nearly proportional to the square root of the size. Above a size of about 3 μ the percentage removal increases slowly until, at a size of 5 μ, about 95% of the particles are removed. It has not

proved possible to explain the square root relationship found between size and percentage removal theoretically, but the calculated displacements due to a combination of sedimentation and Brownian motion appear to be quite adequate to account for the removal of the particles. It appears likely that the larger particles will tend to be deposited in the larger air passages and that, with decrease in size, the particles will tend to be deposited in smaller air passages. Owing to the subsequent expulsion of particles from the larger air passages by physiological mechanisms, the size distribution of the dust in the inhaled air may be a guide to the size distribution of the dust ultimately retained by the lungs. E.J.V.

Pre-employment examinations (North Carolina). M. F. TRICE. *Ind. Med.*, **9**, 188–93 (April, 1940).—Nine references. K.R.

Silicosis and Type III pneumococcus pneumonia: an experimental study. ARTHUR J. VORWALD, ANTHONY B. DELAHANT, AND MORRIS DWORSKI. *Jour. Ind. Hyg. & Toxicol.*, **22** [2] 64–78 (1940).—The unusual susceptibility of the silicotic lung to tuberculosis has led to the inference that such lungs may also be more vulnerable to infection with the pneumococcus. To check the validity of this supposition, experiments were designed to determine the effect of silica on the growth of pneumococcus in artificial culture media and to demonstrate the influence of silicosis upon pneumonia in the living animal. The addition of silica, either in particulate or in dispersed colloidal form, to blood-broth culture medium had no influence on the growth or the morphology of Type III pneumococci. Silicotic rabbits showed no unusual susceptibility to Type III pneumococcus infections produced by intracutaneous injection, by inhalation, or by intrabronchial insufflation. Type III pneumococcus pneumonia, produced experimentally in rabbits with advanced silicosis, ran a normal course, showed no tendency to organize, and resolved as completely as in the normal control rabbits. Silicotic nodules were remarkably resistant to the action of pneumococci and retained, without modification, the distinctive characteristics of such lesions in the rabbits. Persistent perinodular reaction was lacking, and there was no tendency toward the formation of conglomerate fibrosis. The presence of silicosis had no influence upon the well-defined immune reactions to Type III pneumococci that can be elicited in normal rabbits. Their natural resistance to avirulent and virulent strains was maintained, and the resistance acquired from previous infection was apparently as well developed as in nonsilicotic controls. If the length of life is taken as an index of resistance, a small number of observations suggested that, if anything, the presence of silicosis might enhance the resistance of the rabbit to Type III pneumococcus infection. Illustrated. E.J.V.

Edward Ray Weidlein. ANON. *Bull. Amer. Ceram. Soc.*, **19** [9] 344–45 (1940).

BOOKS AND SEPARATE PUBLICATIONS

Chronic Manganese Poisoning in an Ore-Crushing Mill. J. M. DALLA VALLE ET AL. *U. S. Pub. Health Bull.*, No. 247, 77 pp. (1940).—The world manganese industry is thoroughly reviewed. The material used annually by the pottery industry is given in tons. The amount used by the glass industry and how it is used is also given. Two ore-crushing mills were investigated. K.R.

Filtration of the Atmosphere and Its Significance for Dust Sicknesses. G. LEHMANN. Julius Springer, Berlin, 1938. 105 pp., 30 illustrations. Price, paper, 7.50 Rm. *Ergeb. Hyg. Bakt. Immunitätsforsch. Exptl. Therap.*, **19**, 1–87 (1937); reviewed in *Gesundh.-Ing.*, **61** [42] 617 (1938).—L. presents his experimental tests and experiences for avoiding dust sicknesses. An extensive description of various cases is given. The article is of interest to plant physicians and superintendents. The dust-protecting mask is extensively discussed. L. emphasizes the fact that all men, before being hired for work in which they are exposed to dust, should be medically examined in regard to their nasal susceptibility toward dust. According to L., workers with low nasal susceptibility to dust are more susceptible to dust reaction in the lungs. The medical examination is discussed. Great importance is attached to the elimination of fine dust, even particles $^1/_{1000}$ mm. in diameter, from the lungs. W.D.K.

Proceedings of the Sixth National Conference on Labor Legislation. Govt. Printing Office, Washington. *U. S. Dept. Labor, Div. Labor Standards, Bull.*, No. 35, 109 pp. (1940.)—The report of the Committee on Prevention and Compensation of Industrial Injuries and Diseases is given. The Committee recommends (1) compulsory compensation for all industrial injuries, (2) insurance in an exclusive state fund, (3) definition of "injury" to include occupational disease and "blanket" coverage instead of by schedule, (4) unlimited medical and hospital service, and (5) power vested in labor departments or industrial commissions to establish minimum standards of safety and health by the promulgation of industrial health and safety codes. The Committee approved a resolution petitioning that Senate Bill 1620 (Wagner National Health Bill) include provisions making it possible for state labor departments to obtain funds for the furtherance, promotion, and control of industrial hygiene and that labor departments have an equal opportunity with departments of health to secure such funds. See "Reports...," *Ceram. Abs.*, **19** [5] 129 (1940). F.S.M.

Time Study Analyses: Quarry Drilling. Progress Report No. 3. J. R. THOENEN AND E. J. LINTNER. *U. S. Bur. Mines Repts. Investigations*, No. 3502, 19 pp. Free.—Analyses of time studies of primary drilling at a group of quarries are discussed. R.A.H.

PATENT

Joining ceramic objects with metal. RUDOLF SCHARFNAGEL. Ger. 680,064, July 27, 1939 (July 25, 1935); VI/80*b*. 23.01.—Ceramic objects are joined to metal by fusing. The ceramic object is constructed with the metal object to be joined, and at the place of union a binding metal melting at 900° to 1100°C. is applied. The entire unit is heated to 400° to 700°C., and the binding metal is then heated up by high-frequency currents or by blast apparatus to the fusion point. D.A.B.

BIBLIOGRAPHY ON ORTHOSILICATES OF THE ALKALINE EARTHS WITH SPECIAL REFERENCE TO THEIR USE IN THE REFRACTORY FIELD*†

COMPILED BY G. E. SEIL AND STAFF

Calcium Orthosilicate

1. PHILIPPI AND THEUSNER, "Lime and Lime-Alumina Silicates," *Sprechsaal*, **41**, 645–47 (Nov. 12, 1908).—The melting points were determined as follows:

$2CaO \cdot 3SiO_2$	1410°–1420°C. (2570°–2588°F.)	
$CaO \cdot SiO_2$	1490°–1500°C. (2714°–2732°F.)	
$4CaO \cdot 3SiO_2$	1450°C. (2642°F.)	
$2CaO \cdot SiO_2$	1920°–1930°C. (3488°–3506°F.)	Dusted on cooling
$3CaO \cdot SiO_2$	1970°C. (3578°F.)	Dusted on cooling

Conclusions: All Ca silicates are decomposed by water, especially those with a higher CaO content. The silicic acid going into solution is small compared with the amount of lime.

2. K. F. MUKHIN, "Thermochemistry of Metallurgical Dolomite and Utilization of Its Deposits in the Donets Basin for the Production of Lining Material for Steel-Melting Furnaces," *Ukrain. Khem. Zhur.*, **11** [6] 460–68 (1936); **12** [1] 1–16 (1937).—Experiments with various types of dolomites showed that those containing less than 5% or over 9% SiO_2 are not suitable for making lining material. The former have a large amount of CaO, which, because of the insufficiency of H_2SiO_3, is spread throughout the material in the form of large crystals. This facilitates slaking of the dolomites by the atm. moisture. The latter have a large amount of $2CaO \cdot SiO_2$ in the unstable gamma form which promotes disintegration of the dolomite when cooled below 700°C. (1292°F.). Only those dolomites that contain 5 to 9% H_2SiO_3 and at least 2% R_2O_3 are suitable for making lining material. These were prepared at 1450°C. (2642°F.), 1560°C. (2840°F.), 1650°C. (3002°F.), and 1710°C. (3110°F.) by mixing dolomites of the following average compositions: (1) SiO_2 11.3, R_2O_3 5.6, CaO 26.4, MgO 15.2; (2) SiO_2 2.75, R_2O_3 3.5, CaO 29.5, MgO 20.1. In addition, 2% breeze was added. The products were tested for slaking in air, in an autoclave, and in a diphenylmethane calorimeter. Best results were obtained with the product prepared at 1560°C. and of the following composition: SiO_2 6.64, R_2O_3 6.08, Mn_3O_4 0.20, CaO 27.98, and MgO 17.59.

3. B. F. ERDAHL, "Cause of Unsoundness in Portland Cement," *Concrete, Cement Mill Ed.*, **16**, 83–85 (1920).—That unsoundness of Portland cement is due to dicalcium silicate and not to free lime is further established by several experiments. The effect of an addition of $CaSO_4$ to cement for manufacturing supercement is to cause hydration of all Portland cement.

4. N. L. BOWEN, "Genetic Features of Alnoitic Rocks at Isle Cadieux, Que.," *Amer. Jour. Sci.*, [5]**3**, 1–33 (1922).—The compound $2CaO \cdot SiO_2$ occurs in three forms. The beta form with which the natural mineral (lime olivine) corresponds is stable only between 675°C. (1247°F.) and 1420°C. (2588°F.); when pure it changes at room temperature (or higher) to the gamma form, the change being accompanied by such increase of volume that the whole mass is reduced to powder. When embedded in a mass of glass or other minerals, this change is prevented, and in such a case it will persist. It may be noted that the artificial mineral is strongly attacked by water with solution of lime.

5. P. H. BATES AND A. A. KLEIN, "Properties of the Calcium Silicates and Calcium Aluminate Occurring in Normal Portland Cement," *Bur. Standards Tech. Paper*, No. 78 (1917).—A study of the addition of small amounts of the oxides of Ni, V, Mo, Sn, Mg, K, W, B, and Cr to mixtures of SiO_2 and CaO, in the molecular proportion of one of the former and two of the latter, and firing the mixture at a temperature of 1550°C. (2822°F.) for 1 hr. showed that reversion to the gamma form of the $2CaO \cdot SiO_2$ was prevented only in the case of B_2O_3 and Cr_2O_3, the former being used in the form of boracic acid and the latter as the green oxide. These substances in amount less than 1% entirely prevented the reversion of mixtures in the ratio of 2CaO to $1SiO_2$ to the gamma form with one heating for 1 hr. at 1550°C. Two firings of the dicalcium silicate were made, one with the addition of boracic acid and the other with the green Cr_2O_3. The former at 1550°C. seemed to have approached the fusion point a little more closely than the latter, the fired material being a hard glistening white cellular mass; when the Cr_2O_3 was used, a rather soft mottled green material was obtained. In preparing $3CaO \cdot SiO_2$ much more difficulty was encountered. The first firing with the addition of either the boracic acid or Cr_2O_3 produced a material which dusted on cooling to gamma $2CaO \cdot SiO_2$ and free CaO. This material had to be reground and refired five times in order to form $3CaO \cdot SiO_2$. In addition to the above there was fired a $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$ mixture of the limestone and flint to which approximately 1% Al_2O_3 and 0.25% boracic acid were added. The effect of these additions and impurities was very marked in permitting the ready firing of a satisfactory product, only two firings being necessary. These two firings gave a $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$ of greater impurity.

6. SHOICHIRO NAGAI AND KEI-ICHI AKIYAMA, "Studies on the Synthesis of Calcium Silicates: I," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **34** [12] 471–73B (1931).—Equal numbers of molecules of pure $CaCO_3$ and SiO_2 were heated for 1 hr. at temperatures from 900°C. (1652°F.) to 1550°C. (2822°F.). Analysis of the samples indicated that $3CaO \cdot 2SiO_2$ was formed between 900°C. and 1100°C. (2012°F.), $2CaO \cdot SiO_2$ between 1200°C. (2192°F.) and 1400°C. (2552°F.), and $CaO \cdot SiO_2$ above 1450°C. (2642°F.). The hydraulic strength of $CaO \cdot SiO_2$ was less than that of the calcium aluminates but increased with aging in water.

7. S. NAGAI AND K. AKIYAMA, "Synthesis of Calcium Silicates: II–IV," *Jour. Soc. Chem. Ind. Japan*, **35**, 10–15, 161–66, 370–77 (1932); in Suppl. Binding, [1] 8–10B; [2] 65–67B; [3] 118–22B.—Two molecules of pure $CaCO_3$ and 1 mol. of pure SiO_2 were heated to 900° to 1550°C. (1652° to 2822°F.) for 1 hr. The $3CaO \cdot 2SiO_2$ is produced at 900° to 1000°C. (1652° to 1832°F.) and changes gradually to $2CaO \cdot SiO_2$ at 1100° to 1200°C. (2012° to 2192°F.); the yield of the latter increases suddenly at 1450°C. (2642°F.); small quantities of $3CaO \cdot SiO_2$ are produced at 1500°C. (2732°F.) and up. The products obtained by heating at 1400°C. (2552°F.) and up dusted on cooling. Data are given on the strength of the products. With the mixture $3CaCO_3$ and $1SiO_2$ only the $2CaO \cdot SiO_2$ compound was produced at 1400° to 1500°C. (2552° to 2732°F.); heating at 1600°C. (2912°F.) produced a small amount of $3CaO \cdot SiO_2$. All the products of heating at 1400°C. (2552°F.) or up dusted on cooling. The formation of $3CaO \cdot SiO_2$ is accelerated by the presence of Fe_2O_3. The effect of Al_2O_3 on the formation of $3CaO \cdot SiO_2$ is significant, although it is far weaker than that of

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* The paper, "Orthosilicates of the Alkaline Earths with Special Reference to Their Use in the Refractory Field," by G. E. SEIL AND STAFF, will be published in the January, 1941, issue of the *Journal of The American Ceramic Society*.

† The wording of most of these abstracts has been taken from *Chemical Abstracts*. Those published since 1922 have also appeared in *Ceramic Abstracts*.

Fe_2O_3. The effect of Al_2O_3 and of Fe_2O_3 increases with increasing proportions.

8. S. NAGAI AND K. MURAKAMI, "Synthesis of Calcium Silicates: V," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **36** [5] 264–68B (1933).—Pure $CaCO_3$ and SiO_2 in fine powder form were mixed in the ratios $2CaCO_3$:-$1SiO_2$, $2.3CaCO_3$:$1SiO_2$, $2.7CaCO_3$:$1SiO_2$, and $3CaCO_3$:-$1SiO_2$ and heated at 1300°C. (2372°F.), 1350°C. (2462°F.), and 1400°C. (2552°F.) from 0.5 to 12 hr., in some cases with repeated heatings and grindings. CaO and SiO_2 combine completely to dicalcium silicate at 1300°C. in 3 hr. Reaction between $2CaO \cdot 1SiO_2$ and CaO is very slow at the low ratio of $2.3CaO$:$1SiO_2$ and low temperature, but 3 repetitions of heating at 1400°C. for 9 hr. are effective. In all samples, $3CaO \cdot 1SiO_2$ is produced in small amounts and readily formed pure at 1400°C. by repeated heating, grinding, and mixing.

9. S. NAGAI AND KEI-ICHI MURAKAMI, "Synthesis of Calcium Silicates: VI," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **36** [6] 326–30B (1933).—Previous tests were made by heating below 1400°C. (2552°F.). The present tests involve heating above 1400°C. Pure $3CaO \cdot SiO_2$ is produced by heating suitable mixtures to 1450°C. (2642°F.); this compound dissociates very little unless $CaSO_4$ or CaF_2 is present, but Ca_3PO_4, MgO, or $2CaO \cdot SiO_2$ does not cause dissociation.

10. S. NAGAI AND MAKIZO MIYASAKA, "Effect of Fluorides on the Thermal Synthesis of Calcium Silicates: I," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **37** [6] 303–306B (1934).—The effect of fluorspar and other F compounds on the thermal synthesis of silicates was studied. The raw mixtures were made from pure chemicals, $CaCO_3$ or CaO, SiO_2, etc., in the molecular ratios 1:1, 2:1, and 3:1 of $CaCO_3$ (or CaO):SiO_2. The mixtures were heated with or without CaF_2 in a tube furnace. Most of the mixtures were made up with 1% of CaF_2, but others varying from 0.25 to 5.0% were also prepared. The heated products were examined for free CaO, insoluble residue (uncombined or free SiO_2), total CaO, total SiO_2, etc. Experimental results show that with a heating period of 1 hr. the addition of 1% CaF_2 lowers the heating temperature by about 200°C. (392°F.) for a ratio of 1:1 and that the combination of CaO and SiO_2 is considerably promoted by the presence of CaF_2. The molecular ratio CaO:SiO_2 becomes almost 2:1 at about 1000°C. (1832°F.). Experiments on the effect of heating time show that the molecular ratio CaO:SiO_2 decreases with increasing heating period.

11. S. NAGAI AND M. MIYASAKA, "Effect of Fluorides on the Thermal Synthesis of Calcium Silicates: II," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **37** [8] 419–21 (1934).—The effects of CaF_2 additions (0.25 to 5.0%) to mixtures of $2CaCO_3$:$1SiO_2$ and 2CaO:$1SiO_2$ were investigated at temperatures of 1100° to 1400°C. (2012° to 2552°F.). CaF_2 exerted a beneficial influence on the formation of silicates, reducing the temperature of formation and increasing the amounts formed. Most of the CaF_2 remains in the product when heated at 1100° to 1200°C. (2012° to 2192°F.) but may vaporize at higher temperatures (1400° to 1450°C. (2552° to 2642°F.)). Many experimental data are presented.

12. S. NAGAI AND M. MIYASAKA, "Effect of Fluorides on the Thermal Synthesis of Calcium Silicates: III," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **37** [10] 549–52 (1934).—Experimental data show that 70 to 80% of the added fluoride was retained in the dry heated products, which is twice that retained in the hydrothermally heated products.

13. S. NAGAI AND YOSHIO KOSAKI, "Effect of Fluorides on the Thermal Synthesis of Calcium Silicates: VI," *Jour. Soc. Chem. Ind. Japan.* (Suppl. Binding), **38** [6] 229–32 (1935).—Mixtures of $2CaCO_3$:SiO_2 were heated at 1000° to 1400°C. (1832° to 2552°F.) for 1 hr., with and without the addition of 1% CaF_2, and the heats were examined for free CaO, free SiO_2, $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, $3CaO \cdot 2SiO_2$, and $CaO \cdot SiO_2$. With CaF_2 addition, $3CaO \cdot SiO_2$ is easily produced even at 1000° to 1400°C., but its amount decreases gradually at 1300° to 1400°C. (2372° to 2552°F.) and it changes to $2CaO \cdot SiO_2$. The total amounts of Ca silicates produced are considerably greater in the presence of CaF_2. $2CaO \cdot SiO_2$ is also produced in far greater amount. The addition of 1% CaF_2 lowers the reaction temperature by 150°C. (302°F.) for the same degree of combination. The amount of CaF_2 remaining in the heated products is about 75 to 80% of the added amount. Experimental data are given.

14. S. NAGAI AND Y. KOSAKI, "Effect of Fluorides on the Thermal Synthesis of Calcium Silicates: VII," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **38** [7] 294–98 (1935).—A mixture of $2CaCO_3$:SiO_2 was heated for 0.5, 1, 2, and 4 hr. with and without the addition of 1% CaF_2. The longer heating period without CaF_2 was ineffective in regard to the formation of Ca silicates, while the addition of CaF_2 greatly promoted the formation of $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$ and increased the total amount of silicates by about 20%, which is equivalent to a lowering of the heating temperature of about 150°C. (302°F.). Increased amounts of CaF_2 prevented the complete combination by the formation of the eutectic between CaO–$2CaO \cdot SiO_2$–CaF_2, and 0.5 and 1% of CaF_2 gave the best results. The most effective temperature for the formation of $3CaO \cdot SiO_2$ with the addition of CaF_2 was found to be higher than 1300°C. (2372°F.).

15. SEIJI KONDO AND TOSHIYOSHI YAMAUCHI, "Calcium Silicates: I, Synthesis," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **36** [4] 167 (1933).—The effect of temperature on the chemical combination of c.p. CaO and SiO_2 in molecular ratios of 3:1, 2:1, 3:2, and 1:1 was studied. $3CaO \cdot SiO_2$ and $2CaO \cdot SiO_2$ of 100% purity and the other two silicates in very pure condition were obtained.

16. K. HILD AND G. TRÖMEL, "Reaction of Calcium Oxide and Silicic Acid in the Solid State," *Z. Anorg. & Allgem. Chem.*, **215** [4] 333–44 (1933).—The reaction CaO + SiO_2 was studied at 1000°C. (1832°F.) in the molecular ratio of 1:1, X-ray and microscopic examinations being made. The beta $2CaO \cdot SiO_2$ always forms first. This reacts with free SiO_2 still present to form wollastonite, beta $CaO \cdot SiO_2$. An unstable intermediate product, $3CaO \cdot 2SiO_2$, is also formed. With a short reaction time (5 min.) it is possible that the unstable alpha form of $CaO \cdot SiO_2$ is formed.

17. WILHELM JANDER AND ERNA HOFFMANN, "Determination of CaO, $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, $3CaO \cdot 2SiO_2$, $CaO \cdot SiO_2$, and SiO_2 When Existing Together," *Angew. Chem.*, **46** [4] 76–80 (1933).—Free CaO is determined by the formation of Ca glycerate, which, after separation from the undecomposed silicates, is titrated with HCl. If no $3CaO \cdot 2SiO_2$ is present, $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, and $CaO \cdot SiO_2$ together can be determined in aqueous solution by titration with HCl to neutrality when the trisilicates and disilicates are decomposed quantitatively and any $CaO \cdot SiO_2$ remains unchanged. If $3CaO \cdot 2SiO_2$ is present, the other silicates must be determined in the presence of *o*-nitrophenol, and the Ca *o*-nitrophenolate must be titrated with an alcoholic HCl solution. The compound $3CaO \cdot 2SiO_2$ is determined by the addition of HCl to a suspension, but since the decomposition is not quantitative, this introduces some difficulties. An error of about 3% is introduced in the analysis of the four silicates, but free CaO and SiO_2 are determined much more accurately, as is shown by test results which are appended.

18. WILHELM JANDER AND ERNA HOFFMANN, "Reactions in the Solid State at Higher Temperatures: XI, Reaction Between Calcium Oxide and Silicon Dioxide," *Z. Anorg. & Allgem. Chem.*, **218** [2] 211–23 (1934).—Mixtures of $CaCO_3$ and SiO_2 in varying proportions were heated at 1000°C. (1832°F.) and 1200°C. (2192°F.). At the contact surface between a CaO crystal and a grain of SiO_2 there is first formed a skin thin crystalline layer of orthosilicate. For further reactions to occur, CaO must diffuse through the orthosilicate ($2CaO \cdot SiO_2$). If there is a great excess of CaO present and the temperature is sufficiently high, this diffusion occurs so rapidly that only a small quantity of a less basic silicate can be formed. If the temperature does not rise above 1300°C. (2372°F.),

only a small quantity of the most basic compound, $3CaO \cdot SiO_2$, can be formed at the boundary between CaO and $2CaO \cdot SiO_2$. In the absence of excess of CaO or at lower temperatures, the possibility of forming $3CaO \cdot 2SiO_2$ and $CaO \cdot SiO_2$ is greater, and under these conditions the quantity of metasilicate increases. Orthosilicate finally disappears and finally only wollastonite remains.

19. T. W. PARKER AND R. W. NURSE, "Microscopic Examination of Portland Cement Clinker," *Jour. Soc. Chem. Ind.*, **58** [8] 255–61 (1939).—Cement clinker is made up of two principal crystalline constituents ($3CaO \cdot SiO_2$ and $2CaO \cdot SiO_2$) set in a matrix. Small needle- or spear-shaped crystals of $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ and, more rarely, squares or triangles of MgO occur also in the clinker along with grains of free CaO. A mixture of equal volumes of ethylene glycol and absolute alcohol etches $3CaO \cdot SiO_2$ and free CaO; NH_4OAc, or phenol in alcohol, as well as a 10% aqueous solution of $MgSO_4$, also etches the same compounds. Exposure to HF vapor (from a 40% solution) for 10 to 20 sec. etches $2CaO \cdot SiO_2$ (a blue or red color) and $3CaO \cdot SiO_2$ (a straw color).

20. I. WEYER, "Reaction Between Lime and Silica in the Solid Phase," *Z. Anorg. & Allgem. Chem.*, **209** [4] 409–28 (1932).—SiO_2 does not react directly with $CaCO_3$ but with the CaO formed by the decomposition of the latter. Below 735°C. (1355°F.), the primary product is not gamma $2CaO \cdot SiO_2$ but beta $2CaO \cdot SiO_2$, slowly going over into $CaO \cdot SiO_2$ (wollastonite). From 815° to 835°C. (1499° to 1535°F.), beta $CaO \cdot SiO_2$ is formed directly, along with some beta $2CaO \cdot SiO_2$. At higher temperatures, 1050° to 1250°C. (1922° to 2282°F.), beta $CaO \cdot SiO_2$ only is obtained. These results are in agreement with Jander's theory of a concentration gradient in the diffusion of the components.

21. E. P. FLINT AND LANSING S. WELLS, "System Lime–Boric Oxide–Silica," *Jour. Research Nat. Bur. Standards*, **17** [5] 727–52 (1936); R. P. 941.—The equilibrium diagram for the system $CaO–B_2O_3–SiO_2$ is given. The portion of the diagram immediately adjacent to the binary system $B_2O_3–SiO_2$ is incomplete. A unique feature of the system is the appearance of an area of liquid immiscibility extending across the diagram from the $CaO–SiO_2$ side to the $CaO–B_2O_3$ side and crossing the fields of SiO_2, $CaO \cdot B_2O_3$, and $CaO \cdot 2B_2O_3$. A newly established ternary compound, $5CaO \cdot B_2O_3 \cdot SiO_2$, melts congruently at 1419°C. (2586°F.). Tricalcium silicate does not appear at the liquidus in the ternary system. Dicalcium silicate forms partial solid solutions with Ca borates whereby the alpha-beta inversion temperature is lowered by a maximum of 190°C. (374°F.). The evidence indicates that additions of small quantities of B_2O_3 to the Portland cement raw mix before "burning" would not be advantageous.

22. ARTHUR L. DAY, E. S. SHEPHERD, AND F. E. WRIGHT, "Lime-Silica Series of Minerals," *Amer. Jour. Sci.*, [4]**22**, 265–302 (1906).—Of the lime-silica series only one well-defined mineral, wollastonite, is known. Three others correspond to the hypothetical silicic acids, $4CaO \cdot 3SiO_2$, $2CaO \cdot SiO_2$, and $3CaO \cdot SiO_2$. Wollastonite has been studied (Allen, White, and Wright, "Wollastonite and Polymorphic Forms of Calcium Metasilicate," *ibid.*, [4] **21**, 89 (1906)). When lime (free) is once crystallized, it is slowly attacked by water and may be overlooked in ordinary testing. The orthosilicate exists in three forms, and all are attacked by water with the loss of several per cent of their lime. Tests were made on chemically pure materials. *Summary:* There are only two definite compounds of lime and silica capable of existing in contact with the melt. They are (1) the pseudohexagonal metasilicate melting at 1512°C. (2754°F.) and inverting into wollastonite at about 1200°C. (2192°F.); the metasilicate is able to take up a small amount of either lime or silica in solid solution; and (2) the orthosilicate of calcium, which melts at 2080°C. (3776°F.) and possesses three polymorphic forms. The alpha form, which crystallizes in the monoclinic system, has a density of 3.27 and a hardness of between 5 and 6. The beta modification crystallizes in the orthorhombic system and has a density of 3.28. The gamma modification has a density of 2.97 and also crystallizes in the monoclinic system. The disintegration or "dusting" of the orthosilicate and of all lime-silica mixtures above 51% lime is due to the 10% volume change accompanying the beta ⇄ gamma inversion. The alpha to beta inversion point occurs at 1410°C. (2570°F.), and the beta to gamma, at 675°C. (1247°F.). There are three eutectics in the series: tridymite + the metasilicate at 37% CaO, 1417°C. (2583°F.); the metasilicate + orthosilicate at 54% lime, 1430°C. (2606°F.); and orthosilicate + lime at 67½% lime, 2015°C. (3659°F.). The orthosilicate is readily attacked by water, which dissolves out the lime in large quantities. This is probably the reason why it is not found as a natural mineral. The density of fused CaO is 3.32; its hardness, 3+. It fuses in the electric arc, but its fusion temperature is not accurately measurable. Lime crystallizes in the isometric system and possesses no polymorphic forms. Silica begins to melt at about 1600°C. (2912°F.) to an extremely viscous liquid, so that an exact melting point cannot be determined. It has been shown that for all temperatures above 1000°C. (1832°F.), pure quartz changes into tridymite, and pure quartz glass crystallizes as tridymite; above this temperature tridymite is unquestionably the stable phase. In the presence of fused chlorides, silica crystallizes as quartz at temperatures up to 760°C. (1400°F.) and as tridymite above 800°C. (1472°F.); crystalline quartz inverts to tridymite above 800°C., and tridymite goes back to quartz at 750°C. (1382°F.). The inversion temperature is therefore about 800°C. (1472°F.), and the change is enantiotropic. The density of artificial tridymite was found to be 2.318, and that of quartz glass, 2.213. The pure natural quartz used had a density of 2.654; that of the artificial crystals was 2.650. Neither the salt of the trisilicic acid, $2CaO \cdot 3SiO_2$, the akermanite analogue, $4CaO \cdot 3SiO_2$, nor the tricalcic silicate, $3CaO \cdot SiO_2$, can exist in the two-component system. The optical evidence gained by the microscopic study of the crystallized products of mixtures of silicon dioxide and calcium oxide in variable proportions confirms the pyrometric measurements in the following particulars: (1) that silica, calcium metasilicate, calcium orthosilicate, and calcium oxide are the only compounds in the series; (2) that two different modifications of silica exist and correspond in their properties to the minerals quartz and tridymite; that the metasilicate crystallizes in two enantiotropic varieties, one of which is identical with the mineral wollastonite in its characteristics; that three enantiotropic phases of the orthosilicate exist and are stable at different temperatures; and (3) that the metasilicate forms solid solutions both with silicon dioxide and with orthosilicate over limited ranges. The experience gained in the course of the examination of these and other laboratory preparations indicates that the best results can be obtained by observing them in powdered form immersed in liquids of different refractive indices and not in thin sections embedded in Canada balsam. In a liquid whose refractive index is equal to that of one of the component substances of the product, the differences in homogeneity in the product are more readily discerned than in a thin section; at the same time one of the optical constants of the substance is ascertained.

23. W. C. HANSEN AND R. H. BOGUE, "System $CaO–Fe_2O_3–SiO_2$," *Jour. Amer. Chem. Soc.*, **48**, 1261–67 (1926).—Three fields in the $CaO–Fe_2O_3–SiO_2$ system were studied, and equilibrium diagrams were drawn. No optical evidence of the existence of ternary compounds was found, but the existence of $3CaO \cdot SiO_2$ was confirmed. The inversion of $2CaO \cdot SiO_2$ to the gamma form takes place in cooled charges of $CaO–Fe_2O_3–SiO_2$ except where the concentration of the $CaO–Fe_2O_3$ compounds is high. Fe_2O_3 in Portland cement may be present as crystalline $2CaO \cdot Fe_2O_3$ or $CaO \cdot Fe_2O_3$.

24. W. C. HANSEN, "Phase Equilibria in the System $2CaO \cdot SiO_2–MgO–5CaO \cdot 3Al_2O_3$," *Jour. Amer. Chem. Soc.*, 50 [8] 2155–60 (1928).—A study of this system was made to determine the condition of MgO in cement. Samples in which the $2CaO \cdot SiO_2$ varied from 3 to 48.1%, MgO varied from 2 to 11.2%, and $5CaO \cdot 3Al_2O_3$ varied from 40.7

to 95% were melted in Pt and powdered. Portions of these samples were quenched from temperatures between 1290°C. (2354°F.) and 1475°C. (2687°F.). The portions were examined microscopically. Tables and graphs report data on 42 quenchings. MgO does not form solid solutions in $2CaO \cdot SiO_2$ or in $5CaO \cdot 3Al_2O_3$, nor is it capable of replacing CaO in these compounds.

25. James W. Craig, "Manufacturing Magnesitic Brick in Canada," *Jour. Can. Ceram. Soc.*, **7**, 25–35 (1938).—Magnesite rock is converted into dead-burned clinker by firing in rotary kilns to 1788°C. (3250°F.). The reactions in the kiln are as follows: (1) the carbonates decompose, giving off CO_2; (2) the Fe_2O_3 combines with CaO to form a fusible substance called the setting agent; (3) the SiO_2 combines with CaO to form $2CaO \cdot SiO_2$; (4) Fe is gradually adsorbed by MgO and forms periclase; (5) the MgO is rendered resistant to the action of moisture and CO_2 by its crystal structure and dissolved Fe_2O_3. The brick may have either a chemical or a ceramic bond. The forsterite brick is an improvement over either magnesite or chrome refractory as to load-bearing properties and spalling but is not so resistant to high-Fe slags and dust as is the $2CaO \cdot SiO_2$ bond. Basic brick consists essentially of magnesia, chrome, and silicates, separate or in combination. Mineralogically, the Austrian magnesite consists of periclase, magnesioferrite ($MgO \cdot Fe_2O_3$), and silicate fluxes. This brick is characterized by resistance to basic slags, high fusion point, poor load resistance at high temperatures, and poor spalling resistance. Improved spalling resistance has been obtained by substitution of a chemically bonded brick for a fired one and by the correct proportioning of chrome ore and magnesite. Magnecon brick is made by combining magnesite and chrome ore and is characterized by resistance to basic slags, high fusion point, good load resistance at high temperatures, and excellent spalling resistance. Lime-bearing magnesitic brick shows a better resistance to slag erosion than lime-free brick. The phase relations are shown by the equilibrium diagram of the system CaO–MgO–SiO_2.

26. P. P. Budnikov and E. I. Krech, "Effect of Chlorine on Some Calcium Silicates," *Ukrain. Khem. Zhur.*, **12**, 183–89 (in English 189) (1937).—The action of Cl upon pure CaO as well as $CaO \cdot SiO_2$ and $2CaO \cdot SiO_2$ calcined at 1430° to 1470°C. (2606° to 2678°F.) begins at 18° to 23°C. (64.4° to 73.4°F.), and the extent of chlorination is increased with increase in temperature, lowering of the temperature of calcination, and reduction of the particle size. Analytical results show the presence of free CaO in all compounds used.

27. K. Konopicky and H. Kassel, "Sintered Magnesite: I, Determination of the Constituent Minerals," *Ber. Deut. Keram. Ges.*, **17** [10] 465–83 (1936).—The probable constituents in a sinter containing MgO over 80, Fe_2O_3 3 to 11, SiO_2 4, Al_2O_3 2, and CaO 5% were investigated by heating pure oxide mixtures of various compositions at 1500°C. (2732°F.) for 1 hr. In the absence of CaO, the compounds are $2MgO \cdot SiO_2$ and $MgO \cdot Fe_2O_3$. These are obtained by extraction with hot 10% aqueous NH_4NO_3 which leaves the two minerals as an insoluble residue and dissolves only MgO. In the presence of CaO, $CaO \cdot Fe_2O_3$ and $2CaO \cdot Fe_2O_3$ (and compounds with $MgO \cdot Fe_2O_3$) are formed. These are separated by extraction with saturated aqueous sodium tartrate, which dissolves the CaO compounds. The latter also absorb S (in the ratio $3S:1Fe_2O_3$) from Na_2S and assure a dark-green color. As the SiO_2 content increases, the amount of $CaO \cdot MgO \cdot Fe_2O_3$ decreases and disappears entirely when the $CaO:SiO_2$ ratio is 1:1. As long as $CaO\text{-}Fe_2O_3$ compounds are formed, part of the SiO_2 is present as $2CaO \cdot SiO_2$, but in the presence of an excess of SiO_2, monticellite ($CaO \cdot MgO \cdot SiO_2$) is formed. A mixture of $MgO \cdot Fe_2O_3$ and CaO does not react completely after 1 hr. at 1500°C. (2732°F.), but a corresponding mixture of MgO and $CaO \cdot Fe_2O_3$ reacts very readily.

28. K. Konopicky, "Sintered Magnesite: II, Reaction During Sintering," *Ber. Deut. Keram. Ges.*, **18** [3] 97–106 (1937).—Pressed mixtures of MgO, CaO, and Fe_2O_3 were heated 1 hr. at 1300°, 1400°, and 1500°C. (2372°, 2552°, and 2732°F.). The first reactions at low temperature form chiefly MgO compounds, e.g., $MgO \cdot Fe_2O_3$ at 1300° to 1400°C. (2372° to 2552°F.). Only at 1500°C. does $2CaO \cdot Fe_2O_3$ appear. The presence of SiO_2 has no effect at 1300°C., but at 1400°C. $2MgO \cdot SiO_2$ and $2CaO \cdot SiO_2$ begin to form. At 1500°C. no free SiO_2 remains, and $2CaO \cdot SiO_2$ increases at the expense of $2CaO \cdot Fe_2O_3$. The presence of $2CaO \cdot Fe_2O_3$ causes marked sintering of MgO at 1300° to 1400°C. MgO takes $MgO \cdot Fe_2O_3$ into solution at 1500°C. and, on cooling, the ferrite separates again as a mossy structure.

29. K. Konopicky, "Sintered Magnesite: III, Sintering Processes in Magnesites with Unequal Distribution of the Constituents," *Ber. Deut. Keram. Ges.*, **18** [9] 419–27 ('937).—Raw magnesites were coated in the lump form with various fluxing materials (CaO, Fe_2O_3, SiO_2, slag, etc.) and calcined at cones 17 to 18 (1466° to 1485°C. (2670° to 2705°F.)). Only those materials rich in $2CaO \cdot Fe_2O_3$ and poor in SiO_2 caused a good sintering throughout the magnesite lumps. This is in agreement with the observations that raw magnesites sinter well only if their ground mixture consists of an isomorphous mixture of the carbonates of Mg, Fe, and Ca and that the sintering behavior of a magnesite is affected only slightly by the presence of macroscopic pockets or seams of SiO_2, $MgO \cdot SiO_2$, $MgCO_3 \cdot CaCO_3$, etc., which do not themselves sinter. Such unsintered impurities may be removed from the crushed sinter by suitable, e.g., magnetic, physical treatment.

30. M. E. Holmes, W. J. McCaughey, and G. A. Bole, "Dolomitic Clinker as a Stable Basic Refractory," *Rock Products*, **32** [15] 59–67 (1929).—In general, dolomitic clinkers fused above 2015°C. (3660°F.) consist of a non-homogeneous aggregation of crystals of periclase, $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, CaO, and calcium ferrite all bonded with glass. With few exceptions the crystals are small and poorly defined and are not uniformly distributed throughout the mass. All of these clinkers show a tendency to slake upon exposure to warm moist atmosphere. Some of them when heated in steam under pressure will slake to a powder in a few minutes. The system dolomitic limestone (MgO–CaO)–iron oxide–silica was studied, and the effect of substituting Al_2O_3 for Fe_2O_3 was determined. The mixture of stone and fluxes was ground to a fineness of 100% through 100-mesh. The slurry was dewatered, molded into adobes, and dried. The adobes were fired at cones 18, 20, and 26 (1485°, 1520°, and 1595°C. (2705°, 2770°, and 2900°F.)) for 19 to 30 hr. The stability of the product was determined by introducing weighed specimens into an autoclave containing water, heating to 160°C. (320°F.) in 1 hr., cooling in 10 min., and determining the extent of slaking. This procedure was repeated as often as necessary. The experiments showed that a stable product contains over 0.5% Fe_2O_3 and not less than 5% and not over 8 to 12% SiO_2. Some iron oxide, or equivalent, is necessary in order that the SiO_2 may function, but more than a very small amount has no effect other than to reduce the degree of heat treatment required to mature the clinker. Substituting alumina for the iron oxide gives substantially identical results. Clinkers containing 5% SiO_2 or less, except when the Fe_2O_3 is very low, slake from hydration of the lime. Clinkers containing a minimum of 8 to 12% SiO_2 dust to a powder in the manufacturing operation.

31. E. C. Hite and G. Soler, "Refractories for Electric Furnaces," *Brick & Clay Record*, **94** [6] 48, 50, 52, 54; **95** [1] 52–54 (1939).—In the basic electric furnace the refractories are subjected to conditions similar to those found in open-hearth melting, but the slags are more fluid and more corrosive. The penetration of unstable beta $2CaO \cdot SiO_2$ with its subsequent inversion to the stable gamma form on cooling will cause disintegration of the furnace bottom. Continuous operation will prevent the hydration of CaO and the inversion of the silicate. Furnaces with one slag practice are not susceptible to disintegration since the slag carries appreciable quantities of sesquioxides which stabilize the beta $2CaO \cdot SiO_2$.

32. Felix Singer, "Water-Resisting Dolomite Brick; Their Use in War Times," *Brit. Clayworker*, **48** [567]

115–20 (1939); *Ceram. Age*, **35** [2] 40–42, 54–57 (1940).—Rotary kilns operating at 1700°C. (3092°F.) are used to sinter the raw material. Free CaO will hydrate when exposed to air or H_2O and cause disruption. Various fluxes enable the CaO to become dead-burned and more resistant to the action of H_2O. The fluxes are siliceous rocks, clays, labradorite, serpentine, Mn, chromite ore, slags, Portland cement, iron hammer scales, bauxite, quartz powder, borates, etc. The sintered material fired with the addition of these fluxes is crushed, prepared with H_2O, fluxes and H_2O, or organic binders, and fired in kilns. The best brick will disintegrate if boiled in H_2O or stored in a humid atmosphere. Dolomite brick have a higher resistance to load at higher temperatures than magnesite brick. The difference in mechanical strength is due to the reaction of SiO_2 and Fe_2O_3 with MgO, forming $2MgO \cdot SiO_2$ and magnesia ferrosilicate. Forsterite melts at 1810°C. (3290°F.), and the silicate melts at 1350°C. (2462°F.). This low-melting silicate causes the collapse of the magnesite brick, as the load-bearing properties depend upon the matrix. Dolomite brick contain CaO, MgO, SiO_2, and Fe_2O_3. During firing, $2CaO \cdot SiO_2$ is formed and melts at 2130°C. (3866°F.). The binding matrix is more refractory and increases the load-bearing properties. The slag resistance is also superior, as reactions between $2CaO \cdot SiO_2$ and CaO form $3CaO \cdot SiO_2$ which melts at 2190°C. (3974°F.) and is more refractory than the original binding material. The H_2O resistance of the sintered brick is much higher than that of brick made from the raw dolomite, and the brick may be stored for periods up to 6 weeks without hydration.

33. Y. Sanada, "Magnesia in Portland Cement: VII, Effect of MgO on the Preparation of Calcium Silicates," *Jour. Soc. Chem. Ind. Japan* (Suppl. Binding), **41** [1] 10B (1938).—At 1400°C. (2552°F.) the compound $CaO \cdot MgO \cdot SiO_2$ was formed when the CaO/SiO_2 molar ratio was below 2. When it was above 2, the MgO existed free.

34. A. V. Tereshchenko and O. M. Margulis, "Manufacture of Dolomite Brick," *Zitein Tesco*, No. 2268, 6 pp. (1936); abstracted in *Referat. Silikatliteratur*, **4** [3] 3841 (1937).—Crushed raw dolomite with additions of open-hearth slag was mixed, shaped, and fired to 1650°C. (3002°F.). The fired mix was ground, and 4% linseed oil was added. The mix was then pressed, dried for 3 days, and fired to 1450°C. (2642°F.) in an oxidizing atm. The brick had a refractoriness of over cone 40 (1884°C. (3423°F.)), resistance to load of 4.5 kgm. per sq. cm. at 1410°C. (2570°F.) and 2 kgm. per sq. cm. at 1500°C. (2732°F.), water absorption of 6.5%, porosity of 18.3%, specific gravity of 2.75, and hardness of 6.5.

35. G. V. Kukolev and I. E. Dudavskiĭ, "Sintering Process of Highly Refractory Materials: I," *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 45, pp. 1–37 (1939).—A method of sintering highly refractory materials (containing silicates of Ca and Mg) at lower temperatures, for a shorter time, and with a smaller flux content (3.5 to 4% R_2O_3) in the mixes was developed. It is called the "method of active components." The method was used in three ways: (*a*) introduction into the mix of a dispersing material consisting chiefly of gamma $2CaO \cdot SiO_2$, (*b*) introduction of natural silicates of Mg, and (*c*) introduction of double silicates of Ca and Mg. Five types of highly refractory materials were produced: (1) a calcareous refractory (consisting chiefly of $3CaO \cdot SiO_2$) based on CaO and sand as raw materials and the dispersing product gamma $2CaO \cdot SiO_2$; (2) a lime-dolomite refractory (consisting chiefly of $3CaO \cdot SiO_2$ and MgO) based on CaO, sand, and dolomite and the same dispersing product; (3) a refractory composed chiefly of $3CaO \cdot SiO_2$ and MgO produced from a raw material called "zmeevik" (a silicate of Mg) and dolomite; (4) a refractory composed chiefly of $2CaO \cdot SiO_2$ and MgO based on dolomite and sand and synthetic diopside as an active component, containing Fe in solid solution; and (5) a refractory composed of $3CaO \cdot SiO_2$ and MgO on the base of dolomites and sand and the same active component. The refractories obtained possess a high density and high indices of incipient and final softening. Especially high indices were shown by the "zmeevik" dolomite refractories (incipient softening under load at 1620°C. (2948°F.), 4% shrinkage at 1700°C. (3092°F.), and 14% shrinkage at 1750°C. (3182°F.)).

36. Olaf Andersen and Harley C. Lee, "Properties of Tricalcium Silicate from Basic Open-Hearth Steel Slags," *Jour. Wash. Acad. Sci.*, **23**, 338–51 (1933); cf. A. Guttmann and F. Gille, "Microstructure of Tricalcium Silicate and Its Importance in Cement Technique," *Zement*, **22** [16] 204–207; [28] 383–88; [29] 402–405 (1933); *Ceram. Abs.*, **13** [4] 79 (1934).—The physical and chemical properties of most of the constituents of the slags were investigated from the study of well-developed crystals at the laboratory of the U. S. Steel Corp. This paper deals particularly with $3CaO \cdot SiO_2$, which occurs as a main constituent with $2CaO \cdot SiO_2$ and with periclase (MgO), a magnetic oxide, and a lime-bearing ferrite. The light olive-green or brown crystals of $3CaO \cdot SiO_2$ belong to the trigonal system and have a rhombohedral development. The most prominent form on all crystals is the basal pinacoid *C* (0001). It is assumed that their symmetry is of the di-trigonal scalenohedral class. Preliminary work on the study of structure by means of X-ray diffraction patterns indicates that the unit cell is rhombohedral and the crystallographic ratio of $c:a = 1.773$. Cleavage is poor and parallel to the base; hardness is slightly higher than 5. Optical properties are given in detail. Examination of polished surfaces shows that the $3CaO \cdot SiO_2$ can easily be distinguished from its most important associate, $2CaO \cdot SiO_2$, and that all the other constituents can readily be recognized.

37. N. H. Winchell and A. N. Winchell, Elements of Optical Mineralogy: Part II, p. 165. John Wiley & Sons, Inc., New York, 1927.—Shannonite is strongly attacked by water with a solution of lime. It is readily soluble in weak HCl.

38. E. T. Carlson, "Decomposition of $3CaO \cdot SiO_2$ in the Temperature Range 1000° to 1300°C. (1832° to 2372°F.)," *Bur. Standards Jour. Research*, **7** [5] 893–902 (1931); R. P. 381.—Tricalcium silicate tends to dissociate into $2CaO \cdot SiO_2$ and CaO when heated between 1000°C. (1832°F.) and 1300°C. (2372°F.). The amount of decomposition reaches a maximum at about 1175°C. (2147°F.). The decomposition of $3CaO \cdot SiO_2$ is accelerated by the presence of $2CaO \cdot SiO_2$, CaO, and $CaSO_4$.

39. A. I. Korshunova, "Dicalcium Silicate," *Vsesoyuz. Nauch.-Issledovatel. Inst. Tsementov*, No. 17, pp. 34–39 (1937).—A mixture of pure CaO, purified quartz powder, and boric acid heated to 1420°C. (2588°F.) gave a white, hard, and lustrous crystallized mass containing SiO_2 34.12, CaO 63.94, and B_2O_3 0.5%. Petrographic analysis showed the presence of 90 to 95% of beta $2CaO \cdot SiO_2$.

40. B. S. Shvetsov, M. A. Matveev, and Yu. P. Simanov, "Apparatus for Luminescence Analysis and Its Use for the Examination of Silicates," *Keramika*, 1939, No. 8, pp. 5–12.—An a. c. mercury vapor-quartz lamp of 380 to 400 w. is equipped with a filter that transmits ultraviolet rays and with a device for microscopical observation. The apparatus can be used for determining, in slags to be used as rubble, the stability against silicate decomposition due to the transition of beta $2CaO \cdot SiO_2$ to gamma $2CaO \cdot SiO_2$. Stable slags give a homogeneous dark-violet or dark-brown (more rarely bright-violet) luminescence. Older slags sometimes show isolated gold-yellow or silver-white patches or efflorescences due to weathering. Unstable slags show a light breakage surface, multiple iridescent white-yellow and bright-yellow points on a bright-violet ground, and sometimes also rust-brown patches with light-brown points. The method can be used also for determination of the extent of mullitization of fused mullite ware, refractories, porcelain, and other ceramic ware.

41. H. E. Schwiete and H. zur Strassen, "Properties of Cements Rich in Magnesia," *Zement*, **25** [49] 843–46, 861–65, 879–82 (1936).—Equilibrium conditions between CaO, MgO, Al_2O_3, Fe_2O_3, and SiO_2 do not permit MgO to combine with the acidic oxides unless there is not sufficient CaO present to satisfy them completely. $3CaO \cdot SiO_2$ does

not appear until both Al_2O_3 and Fe_2O_3 are fully satisfied with lime. MgO exists only in the free state as periclase, if $3CaO \cdot SiO_2$ is present. MgO may be included as a mixed crystalline phase with $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ up to 2% by weight of the latter. These mixed crystals are the cause of the green color of clinker. The lime compounds normally form in the following manner: $2CaO \cdot SiO_2$, $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$, $3CaO \cdot Al_2O_3$, $2CaO \cdot Fe_2O_3$, $3CaO \cdot SiO_2$; MgO remains uncombined. With undersaturation of CaO, some MgO may appear as spinel, $MgO \cdot (Al,Fe)_2O_3$, provided no $3CaO \cdot SiO_2$ is present. The reactivity of MgO combined with SiO_2, as in blast-furnace slag, is such that at clinker temperatures the MgO is completely replaced by CaO. A late stage in this process is the formation of merwinite, $3CaO \cdot MgO \cdot 2SiO_2$. It is believed that the recommendations of Balthasar (*Tonind.-Ztg.*, **56**, 1016–17 (1932)) are effective in reducing the activity of MgO in cement, viz., addition of Fe_2O_3 and increase of temperature and time of burning. These do not assure freedom from unsoundness, however, over protracted periods of contact with H_2O.

42. G. A. Bole, "Utilization of Dolomite for Refractories," *U. S. Bur. Mines Repts. Investigations*, No. 2627, 11 pp. (1924).—Results of tests made on the dolomites indicate that (1) by using the proper fluxes in proper amounts it is possible to dead-burn dolomite, when properly sized and under proper heat-treatment, to a grain that will not slake, (2) several binders for the ground grains give promise, especially dextrine and Na silicate, and (3) it is possible to form ware by either the semidry or the slip mold method. Details and analyses are given.

43. J. Bied, "Our Knowledge of the Refractory Products Industry," *Chim. & Ind.*, **1**, 579–600 (1918).—B. reviews the progress, during the war, of the French refractory products industry. Dolomitic brick are given considerable space. Slaking before use may be reduced considerably by the addition of 5 to 6% kaolin before firing the carbonate.

44. S. D. Makashev and K. K. Khazanovich, "Reactivity of Silica at Temperatures at Which Portland Cement Clinker Is Fired," *Vsesoyuz. Nauch.-Issledovatel. Inst. Tsementov*, No. 18, pp. 36–56 (1937).—The processes of mineral formation of $2CaO \cdot SiO_2$ in the system $CaO–SiO_2$ depend on the grain size of the silica introduced into the raw mix.

45. V. V. Lapin, "Petrography of Ferrochromium and Ferrotungsten Slags," *Trudy Petrograf. Inst. Akad. Nauk S.S.S.R.*, No. 11, pp. 127–43 (1937); *Mineralog. Abs.*, **7**, 284–85 (1939).—A Fe-Cr slag consists of Mg-Cr spinel, melilite, and alpha $2CaO \cdot SiO_2$; the accumulation of spinel in the lower part is attributed to gravitational differentiation. In another slag there was intergrowth of monticellite and pyroxene.

46. Reinhart, "Refractories of Limestone and Dolomite," *Tonind.-Ztg.*, **63** [2] 15–16; [3] 29–30 (1939).—Ca orthosilicate, melting at 2130°C. (3866°F.), must be stabilized against inversions by the addition of phosphate and borate and against hydration by the presence of oxides of Fe, Cr, and Mn. Addition of MgO yields a basic refractory. Proportioning is discussed.

47. A. T. Kleĭnberg, "Mineralogy of Lime Refractories," *Ogneupory*, **6** [10] 1547–51 (1938).—The firing of $CaO–Fe_2O_3–SiO_2$ batches leads, in an oxidizing medium, to the formation of $2CaO \cdot SiO_2$, $3CaO \cdot SiO_2$, and $2CaO \cdot Fe_2O_3$ and, in a reducing medium, to the formation of ferrous oxides. In firing $CaO–Fe_2O_3$ batches, $2CaO \cdot Fe_2O_3$ forms in the first case, and in the second case, Fe_2O_3 is reduced to metallic Fe.

48. D. A. Nirenshteĭn, "Stabilization of Dolomite Calcined at High Temperatures and the Problem of Dolomite Refractories," *Ogneupory*, **6** [10] 1494–1507; [11] 1572–87 (1938).—N. undertook an investigation to determine the qualitative and quantitative effect of SiO_2, Al_2O_3, and Fe_2O_3 on the properties of calcined dolomite, to study the physicochemical processes taking place in calcining dolomites and the influence of the various oxides, to study the effect of the calcining temperature on the properties, and, based upon these investigations, to determine the properties of calcined dolomites containing different amounts of the above fluxes and the compositions giving a highly refractory product, noncrumbling when cooled, as stable to the influence of moisture as magnesite, and possessing a hardness of about 6 (Mohs' scale). It was found that dolomites containing only one of the above oxides are unsatisfactory. Silica (if present in an amount needed to form $3CaO \cdot SiO_2$ with the CaO of the dolomite) forms, owing to incompleteness of the reaction, $2CaO \cdot SiO_2$, whose inversion leads to crumbling during cooling. If the SiO_2 content is lower, the free CaO remaining leads to instability, owing to the effect of moisture. A high content of SiO_2 alone gives low mechanical strength. Alumina is the most effective flux. Its presence in amounts needed to convert all CaO to $3CaO \cdot Al_2O_3$ leads to a decrease in refractoriness; with lower amounts, too much free CaO remains. Besides $3CaO \cdot Al_2O_3$, Mg aluminates are formed. In some mixtures giving a product satisfying the above requirements, the amount of Al_2O_3 combining with CaO is only 45% of its total content in the mixture. Iron oxide takes an intermediate position in its effect on decreasing refractoriness and on hardness. The presence of Fe_2O_3 only in amounts necessary for complete combination with CaO leads to a decrease in refractoriness; if it is present in amounts not influencing the refractoriness, the free CaO causes instability owing to moisture. The amount of CaO combined with Fe_2O_3 differs considerably from theory, approximating that combined with Al_2O_3. This accounts for the formation of hypothetical ferrite or of a solid solution of CaO in $2CaO \cdot Fe_2O_3$; if the amount of free CaO decreases, it accounts for the formation of $MgO \cdot Al_2O_3$ by a part of the Al_2O_3. In no case was the compound $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ found. Stability to moisture depends on the free CaO content, but to some extent also on density. The firing temperature of dolomites influences greatly the content of free CaO and the hardness of the product. The crumbling of dolomite upon cooling depends not only upon the SiO_2 content but also on the amount of fluxes. When SiO_2 is under 9%, even with different contents of Al_2O_3, no crumbling takes place. Highly refractory dolomite clinker can be obtained when the SiO_2 content is 6 to 9% with a corresponding Al_2O_3 content, or in the case of a 7 to 9% SiO_2 content with a corresponding Fe_2O_3 content. With Al_2O_3 and Fe_2O_3 alone, there is no possibility of obtaining a satisfactory product. The required firing temperature is 1550° to 1600°C. (2822° to 2912°F.). Diagrams show the properties of calcined dolomites containing different amounts of fluxes.

49. J. T. Robson and J. R. Withrow, "Dead Burning of Dolomite: I," *Jour. Amer. Ceram. Soc.*, **7** [1] 61–73 (1924).—*Conclusions:* (1) kaolin appears to be a fairly effective flux for dead-burning dolomite; (2) there are many compounds and eutectics which may form among CaO, MgO, Fe_2O_3, Al_2O_3, and SiO_2; (3) CaO may combine with Fe_2O_3 and act as a solvent for CaO as does also Ca aluminate; (4) the presence of Fe_2O_3 is essential to dead-burn MgO to the stable form, periclase; (5) CaO is rendered inactive to H_2O by calcination in the presence of impurities, especially SiO_2 and silicates; (6) the more MgO present in a lime, the slower it will slake. For Part II see *ibid.*, [2] 141–50.

50. A. B. Searle, Refractory Materials, Charles Griffin and Co., Ltd., London, 1917. Dolomite, pp. 120–21, 250. See reference No. 149, p. 285.

51. L. E. Rivot, *Ann. Mines*, [5]**10**, 505 (1856); from Mellor,* Vol. 6, p. 347.—R. fused a mixture of lime and silica and then separated the free lime by washing. The product was made of $2CaO \cdot SiO_2$.

52. D. Balareff, "Part Played by Water in Reactions Between Solids," *Z. Anorg. & Allgem. Chem.*, **134**, 117–24; **138**, 349–56 (1924); from Mellor,* Vol. 6, p. 348.—B. found that the presence of water and of traces of HCl or H_2S vapor favors the reaction between SiO_2 and CaO; air, H_2, and CO_2 also favor the reaction. It is

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*J. W. Mellor, Comprehensive Treatise on Inorganic and Theoretical Chemistry. Longmans, Green & Co., Ltd., London, 1925.

assumed in some cases that the gas forms a surface skin of, e.g., sulfide or chloride, which fuses easily and brings the two materials in better contact. In other cases, the surface molecules are loosened by the adsorption of the gas, and the effect is comparable with softening or melting.

53. A. GORGEU, *Compt. Rend.*, **99**, 257 (1884); from Mellor,* Vol. 6, p. 351.—G. found $2CaO \cdot SiO_2$ among the products of the action of steam on a mixture of silica and calcium chloride at high temperature.

54. F. DE LALANDE AND M. PRUD'HOMME, *Bull. Soc. Chim.*, [2]**17**, 290 (1872); from Mellor,* Vol. 6, p. 351.

55. W. LÖWENSTEIN, Ueber Lösungen von Kalk und Kieselsäure in geschmolzenem Chlorkalzium, Berlin, 1909; from Mellor,* Vol. 6, p. 351.—In Nos. 54 and 55 the authors obtained $2CaO \cdot SiO_2$ by the action of heat on various mixtures of silica, lime, and calcium chloride.

56. H. LE CHÂTELIER, "Recherches Experimentales sur la Constitution des Mortiers Hydrauliques," Paris, 1884; New York, 1905; *Ann. Mines*, [8]**11**, 345 (1887); "Chemical Reactions and Hardening of Hydraulic Mortars," *Bull. Soc. Chim.*, [2]**42**, 82 (1884); "Constitution of Cements and Theory of Their Hardening," *Compt. Rend.*, **94**, 867 (1882); from Mellor,* Vol. 6, pp. 351, 353.—Le Châtelier found that calcium orthosilicate is readily decomposed by a hot or cold, dilute or concentrated, solution of ammonium salts. The action of acids is still more rapid. The decomposition by bicarbonic acid is much faster than is the case with the metasilicate. Hot or cold water has no appreciable action; only a small proportion was dissolved after a month's action.

57. E. T. ALLEN, W. P. WHITE, AND F. E. WRIGHT, "Wollastonite and Pseudowollastonite, Polymorphic Forms of Calcium Metasilicate," *Amer. Jour. Sci.*, [4]**21**, 89–108 (1906). See reference No. 22, p. 275.

58. C. DOELTER, *Sitzber. Akad. Wiss. Wien*, **120**, 339 (1911); *Tschermak's mineralog. & petrog. Mitt.*, [2]**10**, 83 (1888); from Mellor,* Vol. 6, p. 348.

59. G. A. RANKIN AND F. E. WRIGHT, "Ternary System: CaO–Al_2O_3–SiO_2," *Amer. Jour. Sci.*, [4]**39**, 1–79 (1915); from Mellor,* Vol. 6, p. 348.

60. E. S. SHEPHERD, G. A. RANKIN, AND F. E. WRIGHT, "Binary Systems of Alumina with Silica, Lime, and Magnesia," *Amer. Jour. Sci.*, [4]**28**, 293–333 (1909); from Mellor,* Vol. 6, p. 348.

61. E. S. SHEPHERD, G. A. RANKIN, AND F. E. WRIGHT, "Preliminary Report on the Ternary System CaO–Al_2O_3–SiO_2. Study of Constitution of Portland Cement Clinker," *Jour. Ind. Eng. Chem.*, **3**, 211–27 (1911); from Mellor,* Vol. 6, p. 348.

62. P. NIGGLI, "Recent Mineral Syntheses: III," *Fortschr. Mineral. Krist. & Petrog.*, **8**, 69–89 (1923); from Mellor,* Vol. 6, p. 348.

63. J. B. FERGUSON AND H. E. MERWIN, "Ternary System CaO–MgO–SiO_2," *Amer. Jour. Sci.*, [4]**48**, 81–123 (1919); "Wollastonite and Related Solid Solutions in the Ternary System CaO–MgO–SiO_2," *ibid.*, pp. 165–89; from Mellor,* Vol. 6, p. 348.—References Nos. 57 to 63, inclusive, deal with the thermal diagram of calcium oxide and silica. See reference No. 211, p. 289.

PATENTS

64. W. S. RAWSON AND R. D. LITTLEFIELD, "Process of Manufacturing Refractory Materials," U. S. 683,795, Oct. 1, 1901.—Calcined magnesite is mixed with a small quantity of a fusible boron compound (boron trioxide or boric acid). For magnesite containing a little lime, about 2% of the boron compound may suffice, but when the magnesite contains a considerable portion of lime, the proportion of boron compound may have to be as much as 12%. The mixture is ground, moistened with water, molded, dried, and fired at a high temperature.

65. W. SCHUMACHER, "Increasing the Binding Power of Basic Calcium Silicates," U. S. 1,003,813, Sept. 19, 1911.—The binding power of basic calcium silicates can be increased by the addition of fine quartz powder, the total amount of silicate present in the mixture thus formed not to exceed the amount of lime, and by adding, if desired, other materials, such as lime, gypsum, asphaltum, and stearin, and subjecting the entire mass to the action of steam under pressure.

66. A. KRIEGER, "Refractory Stone Masses," Ger. 294,021, June 5, 1914.—The known magnesia blocks are expensive, and they soften and crumble under the influence of heat. On the other hand, the highly refractory dolomitic stone cannot tolerate moisture since the CaO of the dolomite is slaked, causing deformation. In accordance with the present process, the lime of the dolomite is held in combination, while the MgO, to which is due the refractory nature and resistance to alkali, is present in the free state. With these considerations in view, the dolomite is calcined with quartz or Mg silicates in such proportions that the lime of the dolomite is combined with the SiO_2 or silicates and the MgO remains in the free state. In calcining dolomite and $MgO \cdot SiO_2$ in such proportions that the SiO_2 content corresponds to the CaO of the dolomite, stone masses are obtained which contain still more MgO than does the mixture specified above. The conversion is as follows: $MgO \cdot CaO + MgO \cdot SiO_2 = CaO \cdot SiO_2 \cdot 2MgO$.

67. GEORGE W. PATNOE, "Dolomite Furnace Lining; Furnace Lining and Method of Making," U. S. 1,230,430, June 19, 1917; Can. 192,126, Aug. 12, 1919.—Magnesium limestone is ground with 2 to 5% of argillaceous material containing Al_2O_3, SiO_2, and Fe_2O_3 until substantially all of the mixture will pass through a 100-mesh sieve, and it is then calcined at 1425° to 1650°C. (2597° to 3002°F.) and reduced to a dense sintered mass resistant to air and moisture.

68. A. ROLLASON, "Dolomite Brick, etc.," Brit. 113,199, May 3, 1917.—Brick, etc., are made by calcining dolomite at 1050° to 1350°C. (1922° to 2462°F.) until it becomes semifused, hard, granular, and nonabsorbent, crushing, and mixing with about 1 to 5% of finely crushed dry SiO_2 or siliceous clay. The thoroughly mixed mass is dampened with H_2O or other liquid or is mixed with hot dehydrated tar, molded, and heated in a kiln to the temperature of fusion of the SiO_2 or siliceous clay. The temperature is then raised and maintained slightly above that of fusion, then lowered below the fusion point, and finally slowly raised and maintained at the highest temperature attainable in the kiln.

69. S. G. MCANALLY, "Brick and Furnace Linings from Dead-Burned Magnesite," U. S. 1,305,475, June 3, 1919.—Brick, etc., for furnaces are formed of dead-burned magnesite containing 16 to 18% of lime and 14 to 15% of oxides of Fe, Al, and Si. This material is suitable for lining steel furnaces.

70. D. TYLER, "Alumina," Brit. 172,087, Aug. 24, 1920.—Al ores or Al-containing materials such as clay, slags, or ashes are mixed with CaO or an equivalent Ca or Mg compound in such quantity that there are at least two mol. of CaO, etc., for every mol. of SiO_2 and in addition at least 1 mol. of CaO, etc., for every mol. of Al_2O_3. Allowance is made for any base that may be present. The materials are finely ground and then calcined; a flux such as fluorspar may be added. The product is treated with a solution of an alkali salt such as Na_2CO_3 in order to give alkali aluminate and an insoluble Ca and Mg salt. The former is then treated for the production of Al_2O_3. The $CaO \cdot SiO_2$ which is left after the extraction is particularly suitable in cement manufacturing, since it is free from insoluble alkali salts. Any potash present in the raw material is rendered soluble and is recovered from the alkali left after the precipitation of the Al_2O_3.

71. T. HODSON, J. HODSON, W. HODSON, AND T. A. HODSON, "Dolomite Brick," Brit. 193,576, Dec. 17, 1921.—Dolomite brick are obtained by calcining dolomite, magnesite, or magnesian limestone, adding small quantities (about 15%) of igneous rocks other than granites and syenites, and in some cases a little basic Fe ore, mixing with H_2O, molding, and firing at 2000°C. (3632°F.). Suitable

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* J. W. Mellor, Comprehensive Treatise on Inorganic and Theoretical Chemistry. Longmans, Green & Co., Ltd., London, 1925.

igneous rocks are peridotites (including diorite and gabbro), dolerites (including basalts), serpentines, trachytes, andesites, tachylytes, eurites, and rhyolites. If rocks of the last two classes are employed or if the dolomite contains more than 1% SiO_2 or 57% $CaCO_3$, it is necessary to add 3% basic iron ore, such as titanic iron ore, magnetite, hematite, or göthite.

72. J. Hodson, "Refractory Materials for Lining Furnaces, etc.," Brit. 211,944, Nov. 28, 1922.—Refractory materials are formed from rocks containing $MgCO_3$ and $CaCO_3$ together with (*a*) talc or other Mg silicate, (*b*) igneous rocks with or without basic Fe ores, or (*c*) either *a* or *b* plus silica sand, e.g., SiO_2 15, serpentine 5, raw dolomite 10, and calcined dolomite 70%. The materials may be molded with or without binder and then fired, or they may be fired to a plastic state and then molded. Raw magnesite 92.5, SiO_2 sand 5, and clay 2.5% may also be used.

73. J. Hodson, "Refractory Materials," Brit. 218,720, Jan. 7, 1924.—Natural or calcined $CaCO_3$ or $MgCO_3$ rocks are mixed with materials for preventing hydration and fired at 1550° to 1800°C. (2822° to 3272°F.). The product is broken up or ground, treated with H_2O or a binding liquid, molded, and fired at 1400° to 1500°C. (2552° to 2732°F.). To prevent hydration in the first part of the process, clay, shale, slate, steatite, SiO_2 sand, or igneous rocks such as dolerite, peridotite, and eurite may be used. Na silicate may be used as binder.

74. A. Sprenger, "Refractory Material for Furnace Linings, Crucibles, etc.," Brit. 340,958, Nov. 16, 1929.—Dolomite or the like is melted, and the molten slag is run off and may be cast into brick, etc., which may be tempered and annealed. Oxides of Cr or Al or silicic acid may be added, and the starting material may comprise mixtures of dolomite, magnesite, and lime, magnesite and lime, or lime alone.

75. Cecil S. Garnett, "Refractory Basic Brick from Dolomite," U. S. 1,751,234, March 18, 1930.—Dolomite is calcined until it contains 8 to 12% CO_2; it is ground, treated with a material such as talc and orthoclase together (serving to prevent hydration of the finished product), mixed with water, molded, dried, and fired.

76. W. J. McCaughey (Basic Dolomite, Inc.), "Refractory Material for Furnace Linings, etc.," U. S. 1,839,982, Jan. 5, 1932.—A mixture formed from magnesian limestone and glauconite is fired at a high temperature to form a clinkered granular product.

77. Ture R. Haglund, "Refractory Material," Fr. 740,668, Aug. 2, 1932.—A refractory material containing, after solidification, at least 50% by weight of crystals of spinel from MgO is obtained by fusing a mixture containing, besides spinels, at least 8% of compounds more easily fusible than the latter, such as silicates, titanates, or aluminates, the content of which in oxides of Mg and Ca is either a very small proportion or more than 45%.

78. Arthur T. Cape and Kiel B. Bowman (Republic Steel Corp.), "Stable Dicalcium Silicate Refractory Composition," U. S. 2,015,446, Sept. 24, 1935.—A stabilized silicate refractory material suitable for use in metallurgical furnaces with ferrous metals contains about 65 to 95% of lime, silica combined with a portion of the lime in the form of dicalcium silicate, and about 0.5 to 10% of a phosphate such as tricalcium phosphate or apatite capable of stabilizing the $2CaO \cdot SiO_2$. Na and Ca borates may also be used.

79. Kamillo Konopicky, "Refractory Compositions," Austrian 141,155, March 25, 1935; Cl. 80*c*.—A basic refractory material which has been sintered or fused, e.g., sintered MgO, is mixed with a binder or flux which consists mainly of CaO and Al_2O_3, with or without Fe_2O_3, and contains only subordinate proportions of acidic components such as SiO_2. Alumina cement is a suitable binder. The mixtures may be molded and fired.

80. C. S. Garnett and Garnett Basic Refractories, Ltd., "Refractory Compositions," Brit. 368,798, Sept. 13, 1930; U. S. 1,912,894, June 6, 1933.—Dolomite, calcined or uncalcined, is caused to react with substances, preferably natural rocks, capable of retarding hydration of the finished article to give a material which is molded with a nonaqueous liquid binder, e.g., oil, yielding little or no fixed C and fired.

81. P. P. Budnikov and D. A. Nirenshteĭn, "Refractory Material," Russ. 44,828, Oct. 31, 1935.—Comminuted raw dolomite containing 5 to 8% SiO_2 is mixed with about 15% chrome iron ore, calcined, and ground to be used directly, for lining furnaces, etc., or for refractory brick with or without firing.

82. John D. Sullivan (Battelle Memorial Institute), "Fused Refractory," Can. 373,653, May 10, 1938.—A refractory consisting of SiO_2, magnesia, lime, and Fe or Al oxide contains approximately 2 or 3% of Fe or Al oxide and has a molecular ratio of CaO to SiO_2 of approximately 3 to 1.

83. Heinz H. Chesny, "Magnesia Refractories," Brit. 482,340, March 24, 1938.—These are made by treating sea water or other natural brine containing convertible Mg salts with calcined dolomite or dolomitic limestone, which may be in the form of a slurry, without the application of heat, removing the precipitated $Mg(OH)_2$, and subjecting it to calcination to form a clinker. Substances suitable for binding agents may be introduced into the brine or slurry before precipitation, mixed with the precipitate, or incorporated in the H_2O used for washing the precipitate. Suitable substances are compounds of Ca, Si, Fe, Al, Cr, or Zr. The preparation of a brick is described, wherein the clinker is crushed, sieved, and graded, the graded material being then remixed in the proper proportions, molded, and calcined.

84. Non-Metallic Minerals, Inc., "Refractory Products," Fr. 772,729, Nov. 5, 1934.—Refractory products in which the MgO is agglomerated by Ca ferrite are obtained by heating a mixture giving MgO, not more than 3% of SiO_2, a compound of the nature of Fe oxide, and CaO in amount equal to twice the amount of SiO_2 plus an additional amount sufficient to combine with the Fe oxide. Thus, the mixture may contain SiO_2 1.2 to 2.2, Fe oxide 4.7 to 9.7, and CaO 5.5 to 10.4%.

85. Harley C. Lee (Basic Dolomite, Inc.), "Refractory Material Suitable for Use in Open-Hearth Furnaces, etc.," U. S. 2,078,086, April 20, 1937.—Crushed dolomite particles of substantial size (suitably above 20-mesh) are coated with an adherent film of a clay binder and Fe oxide.

86. Non-Metallic Minerals, Inc., "Refractories," Fr. 804,367, Oct. 22, 1936.—MgO, CaO, and SiO_2 are heated to produce periclase and a durable Ca orthosilicate. The SiO_2 is in a finely divided or hydrated state. Impure MgO, with or without dolomite, may be used, and the heated material may contain small amounts of oxides of B, P, or Cr.

87. C. Arnold (Non-Metallic Minerals, Inc.), "Refractories," Brit. 470,028, Aug. 9, 1937.—Refractory substances containing Ca orthosilicate in substantial amounts and in a stable form, i.e., one that does not at low temperature invert to the low-temperature modification, are made by heating materials that provide SiO_2 in a very finely divided or hydrated condition and CaO, the proportion of CaO to SiO_2 being 1.8 to 2.2:1. MgO in amounts of 35 to 60% of the whole is also preferably present. In an example, dolomite 400, serpentine 160, phosphate rock 2, and H_3BO_3 0.5 parts are mixed, ground to a slurry, and fired at 1538°C. (2800°F.) for 90 min. to form a clinker which is crushed to contain a fairly large proportion of very fine material, mixed with H_2O, and shaped under moderate pressure; the shapes set hard in 24 hr. and can be used as such or refired at about 1454°C. (2650°F.).

88. K. A. Mankau, "Refractory Products," Brit. 23,725, Oct. 17, 1912.—Refractory products are manufactured by forming within them polyacid and polybasic spinels, i.e., spinels containing a number of bases of the RO type and a number of the oxides of the R_2O_3 type, by calcining the dolomite or magnesite containing $CaCO_3$ with a small proportion (up to 6%) of an oxide such as bauxite which contains a certain amount of Fe_2O_3. In a second example, chrome iron ore containing Cr and Al oxides is used as the primary material, which is calcined with a small proportion, about 12%, of raw dolomite.

89. K. A. MANKAU, "Refractory Substance," Brit. 29,082, Dec. 17, 1913.—A refractory substance consists of a limestone to which have been added small quantities of oxides of the type RO and R_2O_3 to produce, on calcining, polyacid and polybasic spinels in the mass (see preceding ref.). The foundation material may consist of limestone to which has been added 4 to 12% of magnesite or chrome Fe ore, in which case the other oxides added are concentrates modified to produce about 6% of a polybasic and polyacid spinel.

90. B. ENRIGHT, "Furnace Lining Material," U. S. 1,319,056, Oct. 21, 1919.—A refractory material for furnace linings is formed of dolomite initially having a considerable SiO_2 content. The material is calcined and after calcination contains Ca and Mg silicates with only a negligible amount of free SiO_2.

91. R. H. MCWILLIAMS, "Refractory Brick Composition," Can. 195,790, Jan. 6, 1920.—A refractory material consisting of dead-burned dolomite with a binder of sintered magnesian limestone has SiO_2 10, FeO and Al_2O_3 10, lime 48, and MgO 32%.

92. GEORGE D. CAIN (Republic Steel Corp.), "Refractory Material Suitable for Metallurgical Furnaces, etc.," U. S. 2,021,222, Nov. 19, 1935.—About 5 to 15 parts of olivine containing MgO about 48, SiO_2 42, and FeO 2 to 20% are used with about 5 to 15 parts of chromite containing $FeO \cdot Cr_2O_3$ and about 5 to 15 parts of calcined dolomite containing CaO and MgO.

93. VEITSCHER MAGNESITWERKE A.-G., "Refractory Brick," Austrian 153,200, April 25, 1938; Cl. 80*d*.—Sintered or fused MgO is mixed with a powdered glass of high melting point, with or without Cr ore, corundum, or other refractory material, and the mixture is fired at a temperature above the melting point of the glass. The proportion of the glass may be up to 20%, and its composition is such that (*a*) the combined percentages of MgO, CaO, and one third of the Al_2O_3, divided by the combined percentages of SiO_2 and two thirds of the Al_2O_3, should be between 0.5 and 1.5, and (*b*) the ratio MgO:CaO should be more than 10, unless the glass contains small proportions of Ti and Mn, in which event the ratio MgO:CaO may be between 0 and 1. The glass may also contain small proportions of alkalis, P_2O_5, and B_2O_3 and may be taken in finer grain than the other refractory materials. Methods of procedure are indicated.

94. W. H. DANIELS, "Refractory Substances," Brit. 365,779, Jan. 20, 1930.—Refractory brick are made by firing a mixture of sintered magnesite, a binder, e.g., concentrated waste sulfite liquor, and a small proportion of 1 to 3% of chrome iron ore, which stabilizes the impurities, e.g., Ca silicates, in the magnesite.

95. N. P. PITT, A. C. HALFERDAHL, AND F. E. LATHE, "Refractories," Fr. 796,160, March 31, 1936.—Refractory materials are made by grinding and intimately mixing calcareous and siliceous substances to give a composition which, when fired, will contain CaO 8 to 76, SiO_2 9 to 40, and Al not more than 5% and will have an effective base–acid ratio of between 1.4 and 3.9 and a hydration value not above 7%, and by firing the composition with a stabilizing agent at above 1426°C. (2599°F.). Examples are given, e.g., dolomite 82.2, chrome ore 6, and sand 11.8%; limestone 65.55, slag 23.55, and sand 10.9%; or dolomite 83.7, chrome ore 1, flakes of Fe oxide 3, and sand 12.3%.

96. N. P. PITT, A. C. HALFERDAHL, AND F. E. LATHE, "Chrome Refractories," Brit. 493,773, Oct. 13, 1938; abstracted in *Trans. Brit. Ceram. Soc.*, **38** [1] 6A (1939).—A sintered refractory clinker in which the silica of chrome ore is converted to dicalcium silicate without the formation of lime spinels is obtained by adding finely ground calcareous material (limestone or calcareous magnesite) to natural chrome ore and firing the mixture at above 1430°C. (2606°F.) but without fusion. The proportion of lime added is sufficient to give a product in which the lime:silica ratio lies between 1.5 and 3.0. The product comprises spinels, dicalcium silicate, and periclase.

97. JULES ERNOULD AND SOC. DES HAUTS FOURNEAUX DE LA CHIERS, "Refractory Brick, etc.," Brit. 440,010 and 440,011, Dec. 18, 1935.—A finely divided mixture of calcined CaO and an oxide of Fe, Cr, or Al is molded under high pressure without the use of a binder, and the molded mixture is fired. In Brit. 440,011, the calcined CaO is replaced by fritted dolomite.

98. A. P. MEYER, "Magnesian (and Dolomite) Refractory Material," U. S. 1,483,468 and 1,483,469, Feb. 12, 1924.—A granular material adopted for bonding at open-hearth furnace temperatures when used as a furnace lining is formed of a hard, dense, angular fired mixture of magnesite and fluxing materials. U. S. 1,483,469 specifies a similar material except that dolomite is used in its preparation.

99. SPENCER B. NEWBERRY, "Basic Firebrick Lining," U. S. 927,585, July 13, 1909.—A mixture of hydraulic cement, lime, and magnesia is made into paste with water, molded, and fired.

100. J. D. SULLIVAN (Battelle Memorial Institute), "Refractory Material Suitable for Furnace Linings, etc.," U. S. 2,098,839, Nov. 9, 1937.—Magnesite grains are bonded together by hydrolysis of a cement formed of a ground clinker consisting mainly of periclase, tricalcium silicate, and Ca ferrite or aluminate which has been fired at a temperature of about 1370°C. (2498°F.) or higher for a sufficient time to render it stable against slaking and dusting.

101. H. E. MASON, "Refractory Brick, etc.," Brit. 16,096, July 6, 1910.—Refractory brick are manufactured by adding to a calcined magnesite mixture a suitable proportion of powdered basic slag as a fluxing agent.

102. A. P. MEYER, "Lining for Basic Open-Hearth Furnaces," U. S. 1,160,085, Nov. 9, 1915.—Granulated dolomitic limestone is calcined, heated to its sintering temperature, cooled, and mixed with sufficient granulated basic open-hearth slag to fill the voids in the sintered material and act as a binder.

103. C. J. BARR, "Furnace Lining," U. S. 1,206,771, Nov. 28, 1916.—Dolomite in granular form is used, coated with slag which serves to set and bond the dolomite.

104. G. S. DAVISON, "Furnace Lining," U. S. 1,210,431, Jan. 2, 1917.—Furnace linings are formed of granules of hard burned dolomitic lime impregnated with such a small amount of basic slag that their faces are substantially free from any layer of the slag.

105. H. A. KENNEDY, "Refractory Products," Brit. 111,853, Nov. 26, 1917; Can. 181,710, Jan. 22, 1918; U. S. 1,238,020, Aug. 21, 1917; U. S. 1,240,148, Sept. 11, 1917.—An intimate mixture of approximately 78 to 92 parts of CaO and MgO, 2 to 13 parts of SiO_2, and Al_2O_3 or Fe_2O_3 or both is clinkered at temperatures higher than that used in Portland cement. To a certain extent, Al_2O_3 and Fe_2O_3 may be replaced by SiO_2, or in their place basic slag, blast-furnace slag, bauxite, chrome iron ore, etc., may be used. Mg limestone or dolomite is preferred as the source of CaO and MgO. The limestone may be first calcined and hydrated, and the materials may be mixed wet or dry. The heating is preferably effected in a rotary kiln by means of a powdered fuel flame, the kiln being inclined less or rotated more slowly than a cement kiln so that the period of heating will be greater. The product is finally cooled in a cooling cylinder and is then ready for use.

106. A. P. MEYER, "Furnace Lining," U. S. 1,300,631, April 15, 1919.—A furnace lining is produced by feeding granular dolomite down through an inclined rotary kiln against flame and flame gases in mixture with 9 to 12% of basic open-hearth granules. The slag is taken up by the dolomite granules, and the temperature is sufficiently high that the dolomite is dead-burned. The dolomite granules may be about 0.19 in. in diameter, and the slag is preferably ground to pass a 50-mesh sieve.

107. A. ROLLASON, "Refractory Substances," Brit. 156,447, April 21, 1920.—Magnesite or dolomite is calcined at 1800°C. (3272°F.) with 5 to 10% basic slag in an internally fired rotary kiln having a basic lining. From the kiln the material passes into an annealing chamber where it is allowed to cool slowly.

108. F. L. DUFFIELD, "Refractory Brick, etc.," Brit. 223,616, April 21, 1924.—Refractory brick are made from

dolomite or other minerals possessing plasticity at high temperatures alone or mixed with fluxing materials such as Fe_2O_3, clay, or basic slag. The material may be heated to 1500°C. (2732°F.), molded under pressure, and then annealed.

109. Louis Veaux, "Basic Refractory Product," Fr. 807,527, Jan. 14, 1937.—A product for lining metallurgical furnaces is composed of a crude basic mineral, such as crude dolomite, mixed with a flux. A binder such as a refractory earth may be added.

110. Rosenthal-Isolatoren G.m.b.H., "Ceramic Masses," Fr. 826,873, April 12, 1938.—P slag, i.e., furnace slag which is a by-product from the manufacture of P and which is composed essentially of Ca silicate, is used as an addition (30 to 60%) in the manufacture of very dense ceramic products containing Al or Mg silicate. The compositions conform to the formulas $CaO \cdot MgO \cdot 2SiO_2$ or $CaO \cdot Al_2O_3 \cdot 2SiO_2$.

111. Erwin Herrmann, "Refractory Materials," Ger. 598,551, June 13, 1934; Cl. 80*b*. 3.01.—A mixture of fireproof clay and limestone is given an addition of Fe_2O_3 or MnO and SiO_2 and sintered to form a fireproof cement.

112. George Witty (Construction Products Corp.), "Refractory Articles Such as Brick for Lining Furnaces," U. S. 2,043,640, June 9, 1936.—A mixture of dolomite 40, blast-furnace slag 30, ganister 20, and bauxite 10 parts, after being calcined, is moistened with a liquid solution containing equal parts of Ca-Mg chloride and $AlCl_3$ to give the mixture a proper consistency and is molded into brick, etc.; these are dried at temperatures of about 93° to 200°C. (199.4° to 392°F.).

113. J. F. Mollen and W. W. Patnol, "Refractory Material," U. S. 1,525,655, Feb. 10, 1925.—A material for lining furnaces and for similar purposes consists of the calcination product of raw dolomite mixed with a minor proportion of argillaceous material and NaCl. The NaCl is eliminated by calcination, and the product comprises about 85% lime and magnesia and may be in the form of heat-compacted masses which are substantially free from dust.

114. Henry Collins, "Making Refractory Material," U. S. 826,763, July 24, 1906.—Siliceous material is mixed with sodium silicate of 140° Twaddell (1.7050 specific gravity) and calcium chloride. The material is molded, and the article is fired without previous drying at a temperature of 1371°C. (2500°F.) to 2204°C. (4000°F.).

115. J. O. Handy and R. M. Isham, "Refractory Material," U. S. 1,270,818 and 1,270,819, July 2, 1918.—A refractory material is formed by moistening granulated dolomite with a solution of $CaCl_2$, drying, and calcining at a high temperature to expel all but less than 1% of Cl from the composition. Granules of this material are formed into brick resistant to the action of air, steam, and H_2O. U. S. 1,270,819 relates to the manufacture of a refractory material by calcining dolomite, extracting with cold H_2O to remove the greater portion, but not all, of the lime (3 to 10% remaining), and then reheating with a small amount of a bonding material such as SiO_2 and Fe_2O_3.

116. N. P. Pitt and E. G. Baker, "Bonding Calcium Silicates," Brit. 492,565, Sept. 22, 1938.—A composition having substantial strength in the unfired condition comprises material containing a substantial amount of physically stable nonhydrating Ca silicate, H_2O, and a bonding agent comprising a carbonate, bicarbonate, fluoride, sulfide, arsenate, dichromate, or hydroxide of an alkali metal, preferably Na_2CO_3. The invention is applicable to all refractory materials containing a substantial proportion, e.g., 20% or more, of $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$ stabilized against hydration and dusting.

117. E. Bertrand, "Composition for Basic Brick," U. S. 413,127, Oct. 15, 1889.—Much harder and more compact dolomite or limestone brick are made by adding to the limestone or dolomite 2 to 4% of basic cinder, i.e., calcareous phosphatic slag, or 1 to 2% basic cinder and 1 to 2% pure iron ore. They are ground very fine and thoroughly mixed together.

118. C. J. Eames, "Bottom for Reducing Furnaces," U. S. 428,747, May 27, 1900.—A mixture of dolomite 75, carbon (coke or graphite) 10, and fluorspar 2% is ground and then intimately mixed with fire sand 7 and fire clay 6%. The whole is worked into a plastic mass with a solution containing 1 pint of sodium silicate in about 5 gallons of water. This plastic mass is applied to the furnace bottom, 4 to 10 in. thick, and gradually fired to drive off the moisture; the heat is finally raised to vitrify or glaze the surface of the bottom. A smooth, durable, iron wearing bottom is obtained.

119. S. B. Newberry, "Basic Firebrick Compound," U. S. 677,688, July 2, 1901.—A calcined dolomite lime containing approximately 58.3% CaO and 41.7% MgO is mixed with about 30% clay or 21% SiO_2. The mixture is moistened with about 5% water, molded into blocks, and calcined at high temperature. The resulting product consists essentially of $3CaO \cdot SiO_2$, $2CaO \cdot Al_2O_3$, and free MgO when made with clay and of $3CaO \cdot SiO_2$ and free MgO when made with silica.

120. M. M. Méran, "Ceramic Product," U. S. 827,550, July 31, 1906.—A strong porous biscuit which is not attacked by acids and bases is obtained by mixing together asbestos (double silicate of lime and magnesia) 70% and steatite (trisilicate of magnesia) 30%. This mixture is pulverized, formed into a paste, molded, and fired just below the vitrification temperature.

121. W. Greaves, "Improvement in the Construction of Coke Ovens to Make Them Proof Against the Action of Alkalis," Brit. 12,210, June 19, 1910.—Calcined magnesium carbonate is mixed with a suitable binding agent such as raw china clay or bauxite in order to bind the whole together and to form a dense hard brick when refired at high temperature. The average analysis of the brick is MgO 89.34, SiO_2 4.96, Al_2O_3 2.85, Fe_2O_3 0.84, and CaO 1.67%.

122. J. O. Handy and R. M. Isham, "Refractory Material from Dolomite," U. S. 1,248,486, Dec. 4, 1917.—Impure dolomite is dead-burned, molded into brick with a temporary binder such as oil, tar, or pitch, and reburned until a permanently nonslaking material resisting the action of hot H_2O is obtained. The product thus formed is suitable for use as a furnace lining, e.g., in basic open-hearth furnaces.

123. F. A. Jones, "Furnace Lining Materials," U. S. 1,251,535, Jan. 1, 1918.—Blast furnace flue dust which contains very fine iron ore, coke, and lime is mixed with water to form a paste. About 10% of flue dust is thoroughly mixed with about 90% of crushed dolomite which goes through a $^1/_2$-in. screen and is retained on a $^1/_8$-in. screen. This mixture is heated from 1093° to 1371°C. (2000° to 2500°F.). The layer of flue dust surrounding the dolomite particles effectively prevents any weathering action of the calcined dolomite. The flue dust may be replaced by talc, serpentine, clay, or salt.

124. R. C. Purdy, M. F. Beecher, and A. A. Klein, "Refractory Article of Magnesia and Alumina," U. S. 1,394,442, Oct. 18, 1921.—A bonded material suitable for lining furnaces or making refractory receptacles is prepared by mixing preshrunk granules of one of the ingredients, MgO or Al_2O_3, with the other of these two ingredients in finely divided condition and heating the mixture to a temperature somewhat below the melting point of any eutectic of the MgO–Al_2O_3 system to effect bonding.

125. H. P. Bassett, "Basic Refractory Composition," U. S. 1,360,355, Nov. 30, 1920.—A composition adapted for use as a lining for furnaces is made by thoroughly mixing together 100 parts of magnesian limestone, 1 to 2% of iron scale or Fe_2O_3, 4 to 6% of silica or other silicon compound, and approximately 2 to 10% common salt. This mixture is heated ordinarily between 1093° to 1371°C. (2000° to 2500°F.). Sufficient water is added to make a soft plastic composition adapted to be readily applied by a shovel or trowel to the interior of the furnace.

126. H. P. Bassett, "Basic Refractory Material," U. S. 1,390,328, Sept. 13, 1921.—The material (adapted for making brick for furnace linings) is formed of double-calcined dolomite 100 to 120, iron oxide 3, borax 1, sodium

silicate 2.5, and Portland cement 5 parts. Ground glass and potter's clay also are used in similar mixtures.

127. WALTER CROW AND J. C. SCHAFFER, "Refractory Brick," U. S. 1,553,143, Sept. 8, 1925.—A refractory material adapted for use in paving, firebrick, or lining furnaces is prepared by heating dolomitic limestone 86 parts, clay 10, iron ore 3, and orthoclase 1.

128. E. BOYNEBURG, "Manufacture of Portland Cement," Fr. 709,740, Jan. 21, 1931; Brit. 355,678, Aug. 19, 1931.—Portland cement rich in MgO is made by employing a raw material containing iron or manganese for binding the magnesia, the minimum of iron oxide necessary amounting to $^2/_3$ of the magnesia or a percentage of 5% and decreasing to $^1/_3$ where the magnesia is 40%.

129. W. J. MCCAUGHEY AND H. C. LEE (Non-Metallic Minerals, Inc.), "Calcined Refractory Magnesia Product," U. S. 1,965,605, July 10, 1934.—A material suitable for patching furnace bottoms, etc., which is obtained by firing magnesia with other components, comprises MgO, less than 3% SiO_2, about 4.7 to 9.7% Fe_2O_3 and Al_2O_3, and lime in a quantity about twice that of the silica plus additional lime equal to about 40 to 70% of the amount of the Fe_2O_3 and the Al_2O_3 together.

130. G. E. SEIL (E. J. Lavino & Co.), "Corrected Basic Refractory," Ital. 359,382, May 20, 1938; Can. 375,880, Aug. 16, 1938; Fr. 832,376, Sept. 26, 1938.—Refractories and brick and other articles made thereof comprise a product obtained by a thermal reaction and containing Ca aluminate, monticellite (if desired, also Ca orthosilicate), and periclase. A primary substance having a basis of lime, magnesia, and silica is mixed with silica and alumina in sufficient quantity to form Ca aluminate, monticellite, and, if desired, Ca orthosilicate with the lime present. The mixture is heated to effect the desired reaction. Ca orthosilicate may be stabilized by adding a phosphate to the mixture. The mixture may be calcined in a furnace to obtain a clinker which is then broken up and converted into brick.

131. G. E. SEIL (E. J. Lavino & Co.), "High Melting Point Silicate Refractory," Ital. 358,697, April 26, 1938; Fr. 832,239, Sept. 23, 1938; U. S. 2,207,557, July 9, 1940.—Mixtures of substances containing CaO, MgO, and SiO_2, e.g., a mixture of dolomite and silica, are heated to produce a refractory material in which the Ca is present in the form of orthosilicate, monticellite, and periclase. The Ca orthosilicate may be stabilized by adding a small proportion of a phosphate to the initial material.

132. H. C. LEE (Non-Metallic Minerals, Inc.), "Periclase and Calcium Orthosilicate Refractory," Can. 369,982, Nov. 16, 1937.—This refractory may have the following chemical composition: MgO 35 to 60, CaO 21 to 40, SiO_2 10 to 22, oxide fluxes, Fe_2O_3, Al_2O_3, Cr_2O_3, 3 to 9, and inversion stabilizing agent, B_2O_3 or P_2O_5, 0.1 to 1.0%. The ratio of lime to silica is kept between 1.8:1 and 2.2:1. The refractory is made by grinding to a slurry that passes through a 100-mesh screen a mixture of southern Nevada magnesite, dolomite, high phosphorus iron ore, and colemanite or magnesite, dolomite, serpentine, iron ore, rock phosphate, and colemanite, and firing the slurry between 1427° and 1649°C. (2600° and 3000°F.). The clinker is crushed to pass an 8-mesh screen, mixed with a small amount of water, and formed into shapes. These shapes are refired at about 1454°C. (2650°F.). Microscopical studies of the finished product show rounded crystals of periclase with elongated interlocking interstitial crystalline calcium orthosilicate.

133. C. E. WILLIAMS AND J. D. SULLIVAN (Battelle Memorial Institute), "Cement," U. S. 1,994,377, March 12, 1935.—A clinker is formed by firing a mixture of a calcareous Mg carbonate material, silica, and a metal oxide fluxing agent, the silica comprising 5 to 11% of the mixture and the metal oxide fluxing agent such as Fe oxide comprising 0.5 to 15% of the mixture, at such a temperature and for such a time as to produce a clinker mainly formed of periclase, tricalcium silicate, and a Ca salt (derived by reaction with the fluxing agent) which is stable against slaking and dusting; the clinker is reduced to powdered form to produce a cement.

134. DOLOMITE, INC., "Decalcification of Mixed Calcium and Magnesium Carbonate Materials," Brit. 363,871, Dec. 31, 1931; Fr. 711,022, Feb. 11, 1931.—Substances such as dolomite are calcined and then treated with a dilute solution of a NH_4 salt to separate the Ca from Mg. The calcined product is treated with dilute NH_4Cl solution to separate the Ca as $CaCl_2$. The remaining product which contains magnesite and small amounts of iron, aluminum, silicon, and manganese is calcined at a high temperature to form a highly refractory material of particular value for furnace usage.

135. K. P. MCELROY, "Refractory for Open-Hearth Furnaces," U. S. 1,551,201, Aug. 25, 1925.—Dolomite or magnesian limestone is crushed to pass through a $^3/_{16}$- or $^1/_{16}$-in. screen. The fines (minus 50-mesh), which are less refractory than the coarser portion, are screened off, 8 to 15% fines are mixed with the coarse dolomite and fired in a rotary kiln at about 1705°C. (3100°F.) which is approximately the temperature of the open-hearth furnace. The fines liquefy in such a fine form that they impregnate and surface coat the granular material without bonding together. Finely ground alumina, silica, iron oxide, mill scale, or basic open-hearth slag may be used in place of the fine portion of dolomite.

136. N. P. PITT, A. C. HALFERDAHL, AND F. E. LATHE, "Refractories," Can. 363,778, Feb. 2, 1937; Brit. 450,961, July 27, 1936.—A basic refractory with a hydration value not exceeding 7% contains lime 8 to 76%, SiO_2 9 to 40%, and an effective base-acid ratio,

$$\frac{\%\ CaO + \frac{\%\ MgO}{15}}{\%\ SiO_2 + \frac{\%\ Fe_2O_3 + \%\ Cr_2O_3 + \%\ Al_2O_3,\ etc.}{10}},$$

between 1.40 and 3.90. As stabilizing agents, chromite, apatite, iron ore, manganese ore, mill scale, basic open-hearth and converter slags, phosphates, fluorides, borates, etc., or mixtures thereof, may be used from 1 to 8%. The raw constituents and the stabilizing agents are finely ground, thoroughly mixed, and fired between 1482° and 1760°C. (2700° and 3200°F.).

137. PRIVATE COMMUNICATION, "Basic Refractories."—A refractory product composed mainly of periclase and calcium orthosilicate is made by mixing and grinding to a slurry 400 lb. of northwestern Ohio dolomite, 160 lb. of Maryland serpentine or 144 lb. of North Carolina dunite, 2 lb. of 20% phosphate fertilizer, and 5 oz. of boric acid. This slurry is gradually fired at a temperature of 1538°C. (2800°F.) in 1 to $^1/_2$ hr. The clinker is crushed to pass an 8-mesh screen, mixed with a little water, and pressed into shapes. These shapes may be used as such or dried and refired at a temperature of 1454°C. (2650°F.) to obtain a hard and dense brick resistant to spalling. The R_2O_3 (Fe_2O_3, Al_2O_3, and Cr_2O_3) present should be from 4 to 8%.

138. PRIVATE COMMUNICATION, "Basic Refractories and Methods of Making."—The best combination of refractoriness and strength at high temperatures was obtained in accordance with the following procedure: To 100 parts of crude magnesia of the chemical composition SiO_2 0.75, Al_2O_3 0.30, Fe_2O_3 0.20, CaO 0.50, and MgO 98.25%, 2.5 parts of silica and 3.5 parts of lime were added. These materials were thoroughly mixed and fired at about 1650°C. (3000°F.). The product obtained had the chemical analysis SiO_2 4.30, Al_2O_3 0.40, Fe_2O_3 0.30, CaO 5.30, and MgO 89.70% and the following petrographic analysis: a matrix largely composed of monticellite and about 86.6% periclase as a disperse phase. 100 parts of this composition with 3.35 parts of lime added were mixed together, ground to the proper grain size, and mixed with dextrine to form an unfired brick which, upon subjection to partial fusion, will develop a structure of periclase in a matrix largely composed of $2CaO \cdot SiO_2$. Traces of P_2O_5 may be added to stabilize the $2CaO \cdot SiO_2$.

139. PRIVATE COMMUNICATION, "Refractories and Method of Making."—A heat-hardening basic refractory was made of fired magnesite containing MgO 65 to 90,

SiO_2 2 to 9, Al_2O_3 1 to 4, CaO 2 to 6, and Fe_2O_3 up to 10%; most of the CaO was present as monticellite and the alumina as magnesium aluminate. This fired magnesite, which had a softening point between 1371° and 1530°C. (2500° and 2800°F.), was graded to pass a $^3/_8$-in.-mesh screen and remain on a 10-mesh screen and was then mixed with calcined dolomite containing CaO 30 to 60, MgO 30 to 50, and SiO_2 4 to 8%. The calcined dolomite was present in sufficient amount to supply enough CaO for the conversion of the monticellite to $2CaO \cdot SiO_2$ and the magnesium aluminate to $3CaO \cdot Al_2O_3$. The final product supported a load of 20 lb. per sq. in. at about 1649°C. (3000°F.).

Forsterite

140. G. A. Rankin and H. E. Merwin, "Ternary System MgO–Al_2O_3–SiO_2," *Amer. Jour. Sci.*, [4]**45**, 301–25 (1918).—The temperature-concentration relations of the various crystal phases in equilibrium with liquid in the ternary system MgO–Al_2O_3–SiO_2 were investigated, and the results are represented by diagrams and a model. The crystalline substances found to be stable in contact with liquid are MgO (periclase), Al_2O_3 (corundum), SiO_2 (tridymite, cristobalite), $2MgO \cdot SiO_2$ (forsterite), $MgO \cdot SiO_2$ (clinoenstatite), $MgO \cdot Al_2O_3$ (spinel), $Al_2O_3 \cdot SiO_2$ (sillimanite), and a ternary compound, $2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$ (cordierite). Of these, clinoenstatite and cordierite are unstable, and, when pure, dissociate when melting begins.

141. Wilhelm Jander and Josef Wuhrer, "Reactions in the Solid State at Higher Temperatures: XIII, Reaction Course in the Formation of Magnesium, Strontium, and Barium Silicates," *Z. Anorg. & Allgem. Chem.*, **226** [3] 225–47 (1936).—In the reaction between MgO or alkaline-earth oxides and SiO_2 in the solid state, orthosilicate formation is favored, and this occurs as the primary product in most cases. It is only in exceptional cases that the formation of metasilicates takes place more easily. When freshly precipitated SiO_2 and $CaCO_3$ are mixed in H_2O, they react to form metasilicate, and this is likewise true of the reaction between talc and $MgCl_2$. The preference for orthosilicate formation over metasilicate is explained as follows: (1) the heat content of orthosilicate is greater than that of other silicates; (2) the activation energy is conversely smaller; (3) the production of crystallized orthosilicates is easier; nucleus formation and velocity of growth are better; and (4) the structural similarity between the raw materials and the reaction products is likewise a factor. In orthosilicates, each Si atom is surrounded by 4 O atoms to form a tetrahedron; with metasilicates, long open chains are formed.

142. Seiji Kondo, Teiroku Sueno, and Hiroshi Yoshida, "Magnesite Refractories: I, Microstructure of South Manchurian Magnesites Fired at Different Temperatures," *Jour. Japan. Ceram. Assn.*, **40** [475] 422–36 (1932).—South Manchurian magnesites were heated at constant temperatures from 1200°C. (2192°F.) to 1800°C. (3272°F.) for 1 hr. and then examined for microstructures. The chief phases observed were periclase, amorphous MgO, forsterite, and clinoenstatite. The volume percentage of olivine, spinel, and periclase calculated from the chemical compositions agreed well with the results of the microscopic determinations. The magnesites changed greatly at 1200° to 1300°C. (2192° to 2372°F.) and 1600° to 1700°C. (2912° to 3092°F.). At 1200° to 1300°C. clinoenstatite and amorphous MgO changed almost completely to forsterite and periclase, respectively. At 1600° to 1700°C. forsterite melted and filled the voids of the periclase crystals, developing the so-called poikilitic structure. The more SiO_2 present in the magnesites, the greater was the rate of recrystallization. A Seizanhai magnesite mixed with various oxides was calcined at 1000°C. (1832°F.), formed into tablets, and fired to cones 26, 28, and 30 (1596°, 1615°, and 1650°C. (2900°, 2940°, and 3000°F.)) in a gas-fired kiln; thin sections were examined under a microscope. Adding SiO_2 favored the development of periclase and caused the formation of minute crystals of magnesioferrite. Cr_2O_3 seemed to dissolve in forsterite. Al_2O_3 favored the development of periclase and produced a poikilitic structure, probably due to the formation of cordierite which melts at a comparatively low temperature.

143. Longchambon and Ko-Fuh-Tsiang, "Researches on Magnesia Refractories," *Rev. Mét.*, **28** [6] 324–29 (1931).—Test samples were made by industrial methods from specially prepared MgO. Calcining 1 hr. at 600°C. (1112°F.) gave a density of 2.9. Higher temperatures up to 1500°C. (2732°F.) increase the density to 3.5. An addition of SiO_2 lowers the density and shrinkage; Fe_2O_3 has an opposite effect. Either oxide is an excellent agglomerant in the cold but lowers the softening temperature. Al_2O_3 makes the brick less refractory. CaO alone, even in a small amount, promotes crumbling, but when it is added with Fe_2O_3 the product has a very high softening point, 200°C. (392°F.) higher than commercial samples. Adding a mixture of SiO_2 and CaO or SiO_2 and Fe_2O_3 makes inferior brick. Molding pressures up to 10 kgm. per sq. cm. have little effect. The temperature at which bending commences is raised by increasing the calcination temperature.

144. V. Iskvul, Experimental Investigations on the Chemical Constitution of the Silicates: The Chlorites. Private Publication, Petrograd, 1917. 310 pp. *Mineralog. Abs.*, **2**, 207–15.—Olivines are certainly orthosilicates, as indicated by the entirely different solubility of SiO_2 in the olivines and the metasilicates, enstatite and bronzite. On ignition of olivine, FeO is oxidized to Fe_2O_3, the upper limit being 83% of the total FeO (in forsterite). The reaction is $2FeO \cdot SiO_2 + O = Fe_2O_3 + SiO_2$ and then $2MgO \cdot SiO_2 + SiO_2 = MgO \cdot SiO_2$. The amphiboles have a SiO_2 solubility twice as great as that of the pyroxenes. Solubility experiments on ignited serpentine prove that the reaction $2H_2O \cdot 3MgO \cdot 2SiO_2 = 2H_2O + 2MgO \cdot SiO_2$ takes place. Serpentines are metasilicates, and compact serpentine and chrysotile are pyroxene silicates similar to enstatite, while antigorite is similar to anthophyllite.

145. N. L. Bowen and O. Andersen, "Binary System MgO–SiO_2," *Amer. Jour. Sci.* [4]**37**, 487–500 (1914).—The thermal diagram of the binary system MgO–SiO_2 indicates that both the orthosilicate and the metasilicate can exist in contact with the liquid. The maximum corresponding with the orthosilicate is at 1890° ± 20°C. (3434° ± 68°F.), and the eutectic with MgO and the orthosilicate is at 1850° ± 20°C. (3362° ± 68°F.), at which the mixture has 14% of MgO and 86% of the orthosilicate. The eutectic with SiO_2 and magnesium metasilicate as solid phases has 12.5% of the former and 87.5% of the latter, and the temperature is 1543° ± 20°C. (2809° ± 68°F.).

146. W. Büssem and C. Schusterius, "Constitution of Steatite: I, Crystalline Phase," *Wiss. Veröffentl. Siemens-Werken*, **17** [1] 59–77 (1938).—On heating MgO with quartz, forsterite was formed at 1200°C. (2192°F.), while protoenstatite began to appear at 1400°C. (2552°F.). If the samples were pulverized, clinoenstatite tended to appear in place of protoenstatite. The formation of clinoenstatite was also promoted by the use of hydrated SiO_2 in place of quartz and by the presence of mineralizers such as Li_2O, fluorspar, H_3BO_3, and borax.

147. O. L. Kowalke and O. A. Hougen, "Crushing Strength of Magnesia-Silica Mixtures at High Temperature," *Trans. Amer. Electrochem. Soc.*, **33**, 215 (1918).—Magnesia and silica of high purity were mixed in varying proportions and fired at various temperatures, and cylinders of the mixtures were subjected to pressure in an electric furnace. The pressure was applied by a C rod at carefully measured temperatures. The temperature at which the cylinders crushed when subjected to a definite applied pressure was noted. A mixture containing 7.5% SiO_2 failed at about 1870°C. (3398°F.), which was 190°C. (374°F.) higher than magnesia supported. The superiority of this mixture appeared to be due to the envelope of forsterite which cemented the grains of periclase, and failure is due to a softening of the forsterite.

Above 2000°, carbon attacked magnesia-silica mixtures very rapidly. The electric furnace and the arrangement of the cylinder for test are illustrated, and photomicrographs support the theory of the formation of compounds between MgO and SiO_2 at the various temperatures.

148. V. V. Goncharov and A. T. Kleĭnberg, "Mineralogy of Forsterite Refractories," *Ogneupory*, **4**, 205–13 (1936).—To obtain highly refractory mixtures from talc-magnesite minerals, the right amount of $MgCO_3$ must be added to form a forsterite-periclase or forsterite composition. Practically, the latter is more easily obtained. This composition results from the interreaction of $MgCO_3$ and talc, the latter retaining its constant phase composition from the moment of complete dehydration to the higher firing temperatures. Differences in mineralogical composition of the products obtained result from variations in the preparation and heat-treatment. Quantitatively, the reaction is sufficiently complete at 1450° to 1500°C. (2642° to 2732°F.); this temperature is recommended for firing. Larger crystals of forsterite and a denser mass result from a longer time at the final firing temperature. The rate of cooling does not influence the composition and microstructure. Higher pressure during forming results in a denser mass richer in forsterite. The same result is obtained by a preliminary firing of talc. Increasing the firing temperature from 1600° to 1700°C. (2912° to 3092°F.) increases greatly the completeness of the reaction. The presence of Fe_2O_3 leads to the formation of magnesioferrite, which impedes the reaction.

149. A. B. Searle, Refractory Materials, pp. 389–90. Chas. Griffin and Co., Ltd., London, 1924.—Two forms of magnesia occur in the brick, viz., amorphous magnesia (specific gravity 3.0 to 3.2) and periclase (specific gravity 3.4 to 3.6). This is due to the fact that amorphous magnesia is formed first and is slowly changed into periclase when heated to a temperature above 1200°C. (2192°F.). In practice, it is necessary to fire the raw material or the brick at a much higher temperature in order to secure the complete conversion of the magnesite, a temperature of 1450°C. (2642°F.) to 1700°C. (3092°F.) being necessary according to the nature of the material and the size of the pieces. Very small quantities of magnesite can be converted into periclase at a much lower temperature than larger ones, as the heat penetrates the latter very slowly. In brick containing much lime and silica, the polygonal shape of the periclase crystals is largely destroyed, the grains being rounded and set in a matrix of impurities. The rate at which the change takes place is increased in the presence of certain impurities, such as iron oxide, which combine with the magnesia to form a molten slag having a powerful solvent action on the unaltered magnesia and result in its rapid conversion into the denser form equivalent to amorphous periclase. The conversion is naturally more rapid when the impurities are uniformly distributed through the mass than where they are not in such intimate contact. It is advantageous to have as much as possible of the magnesia converted into periclase, as the latter is fully shrunk and will not change in volume during any later heating. Magnesia brick also contain various compounds of magnesia with other oxides, the most important being (1) magnesium ferrate ($MgO \cdot Fe_2O_3$), which is a dark-colored, brown, or black compound first detected in magnesia brick by F. Cornu and confirmed by Cronshaw; and (2) forsterite, a magnesium silicate ($2MgO \cdot SiO_2$), which is formed (usually at a temperature above 1500°C. (2732°F.)) when silica is present. According to Kowalke and Hougen (see ref. No. 124) the forsterite crystals completely enclose the periclase crystals, binding them firmly together and forming a very strong mass. For this reason, Continental users attach much importance to the presence of at least 5% of silica, and when less than this proportion is present some manufacturers add an equivalent amount of clay. A. Scott has reported the occurrence of a substance similar to the mineral monticellite ($MgO \cdot CaO \cdot SiO_2$) in some British magnesite brick. The other impurities in magnesia brick are similar to those in fire-clay and silica brick. See reference No. 50, p. 278.

150. R. A. Heindl and W. L. Pendergast, "Olivine as a Refractory," *Bur. Standards Jour. Research*, **12** [2] 215–22 (1934); R. P. 645.—Chemical analyses showed that the silica ranged from approximately 40 to 45%, magnesium oxide 40 to 49%, and iron as ferrous oxide 7 to 15%, with lesser amounts of alumina, calcium, and titanium. The rate of thermal expansion was fairly regular from room temperature to 900°C. (1652°F.), except for slight irregularities between approximately 200° and 300°C. (392° and 572°F.) and 650° and 700°C. (1202° and 1292°F.). These irregularities were less evident in the heated material than in the raw material. The total expansion from 20° to 900°C. (68° to 1652°F.) ranged from 0.942 to 1.082% and was somewhat lower than that of magnesite. The true specific gravity ranged between 3.206 and 3.420 for the raw material and between 3.294 and 3.434 for the material heated at 1400°C. (2552°F.). The specific gravity of the materials low in calcium oxide was decreased by heating. The P.C.E. (softening point) of the raw ore ranged from 30 to above 35 (1649° to 1785°C. (3000° to 3245°F.)), except that of the material high in calcium oxide which varied from 11 to 16 (1285° to 1450°C. (2345° to 2642°F.)). The P.C.E. of the raw material was not necessarily the same as that obtained on the material after heating at 1400°C. (2552°F.). The olivines from North Carolina were more refractory than those from the other sources. Petrographic analyses were made on the olivines before and after the various heat treatments. The principal result of heating the olivines to 1400°C. (2552°F.) or higher was the apparent removal of the fayalite from the solid solution series (and its subsequent decomposition), leaving the olivines composed almost wholly of forsterite.

151. A. F. Greaves-Walker and R. L. Stone, "Production of Unfired and Fired Forsterite Refractories from North Carolina Dunites," *North Carolina State Coll. Eng. Expt. Sta. Bull.*, No. 16, 123 pp. (1938).—The olivine deposits of North Carolina are discussed. Experimental results are given on the determination of the correct grain size and other factors for greatest compressive strength of forsterite refractories. Dunite can be substantially purified by eliminating antigorite and chlorite during grinding, crushing, and screening operations by discarding material retained on a 20-mesh screen. Only bonding agents gave satisfactory results for an unfired forsterite refractory, viz., Lumnite cement (7.4 to 9.1%), a high Al_2O_3 hydraulic cement, and Na silicate (not over 2.92% calculated on the anhydrous solid basis). Liquid Na silicate having a $Na_2O:SiO_2$ ratio of 1.00:3.22 gave the best results. A material rich in MgO, such as magnesite or high MgO dolomite, must be used as the conversion agent. Cr_2O_3, to form chromite with the FeO, in conjunction with MgO-rich material, to form forsterite, is very satisfactory. The MgO-rich material should be added in an amount sufficient to introduce at least 7.41% MgO into the mix. The mixture of MgO-rich material and olivine should be calcined at temperatures of 1621° to 1649°C. (2950° to 3000°F.) to produce a refractory stable at 1482° C. (2700°F.) or above in order to make conversion complete. The unfired refractories should preferably be made entirely of calcine, as the introduction of raw olivine is detrimental. The fired refractories can be made of mixes containing up to 25% crude olivine, if fired to cone 30 (1649°C. (3000°F.)). The calcine could be produced in a rotary cement kiln and should be crushed to pass 6 mesh and screened on a 60-mesh sieve. Any material passing 60-mesh should be discarded as it contains the largest portion of the magnesioferrite.

152. R. L. Stone, "Thermochemistry of North Carolina Olivine in the Manufacture of Forsterite Refractories," *Jour. Amer. Ceram. Soc.*, **22** [10] 342–48 (1939).—The main cause of failure of forsterite refractories is the incomplete conversion of impurities. Firing to 1593°C. (2900°F.) or preferably 1649°C. (3000°F.) or above is necessary. MgO or MgO-rich material may be used with crushed olivine to eliminate the glassy phase. During firing, the fayalite and hydrosilicates of Mg are decomposed. FeO is completely removed from the fayalite at

704°C. (1300°F.) and is deposited as Fe_2O_3 in the cleavage planes of the remaining forsterite material. At higher temperatures, the Fe_2O_3 is converted to Fe_3O_4. In the presence of MgO, the Fe_3O_4 is converted at 1593°C. (2900°F.) to $MgO \cdot Fe_2O_3$ in an atmosphere alternately oxidizing and reducing to Fe_3O_4; at 148.9°C. (300°F.) or higher the formation of $MgO \cdot Fe_2O_3$ takes place in an oxidizing atmosphere. The SiO_2 from the fayalite produces a simple MgO–SiO_2 system with no liquid phase below 1307°C. (2385°F.), at which temperature approximately 10% of the mass of forsterite material becomes liquid. Free O in the atmosphere is essential to the decomposition of the fayalite.

153. A. V. Rudneva, "Change of Structure and Mineralogical Composition of Serpentines and Dunites on Firing," *Ogneupory*, **7** [1] 54–61 (1939).—By optical and X-ray methods the products obtained by heating serpentines and dunites at 600°C. (1112°F.), 1000°C. (1832°F.), 1300°C. (2372°F.), 1400°C. (2552°F.), and 1500°C. (2732°F.) were investigated (+ indicates mineral appears; − indicates mineral disappears).

Serpentines		Dunites
	1500°C. / 2732°F.	+ Fayalite ($2FeO \cdot SiO_2$)
	1400°C. / 2552°F.	− Glass
		− Enstatite ($MgO \cdot SiO_2$)
+ Spinel ($MgO \cdot Al_2O_3$)		
+ Clinoenstatite ($MgO \cdot SiO_2$)		
+ Forsterite ($2MgO \cdot SiO_2$)		
		+ Forsterite ($2MgO \cdot SiO_2$)
+ Periclase (MgO)	1300°C. / 2372°F.	
− Magnesite ($MgCO_3$)		− Olivine ($(2MgFe)O \cdot SiO_2$)
− Pseudoanthophyllite ($(MgFe)O \cdot SiO_2$)		− Pseudoanthophyllite ($(MgFe)O \cdot SiO_2$)
− Glass		
+ Pseudoanthophyllite ($(MgFe)O \cdot SiO_2$)		+ Glass; present up to 1400°C. (2552°F.)
− Antigorite ($3MgO \cdot 2SiO_2 \cdot 2H_2O$)	1000°C. / 1832°F.	+ Enstatite ($MgO \cdot SiO_2$); present up to 1400°C. (2552°F.)
− Chrysotile ($3MgO \cdot 2SiO_2 \cdot 2H_2O$); disappears below 1000°C. (1832°F.)		+ Periclase (MgO)
		− Magnesite ($MgCO_3$)
		− Antigorite ($3MgO \cdot 2SiO_2 \cdot 2H_2O$)
+ Glass	600°C. / 1112°F.	
Magnetite ($FeO \cdot Fe_2O_3$); present at all temperatures		Magnetite ($FeO \cdot Fe_2O_3$) and spinel ($MgO \cdot Al_2O_3$) inclusions; present at all temperatures
		Chromite; present in all cases.

154. F. A. Harvey and R. E. Birch, "Olivine and Forsterite Refractories in America," *Ind. Eng. Chem.*, **30** [1] 27–32 (1938).—The preparation of forsterite brick by firing olivine and MgO was independently developed in the United States.

155. V. M. Goldschmidt, "Olivine and Forsterite Refractories in Europe," *Ind. Eng. Chem.*, **30** [1] 32–34 (1938).—Olivine is fired in contact with magnesite to yield a refractory product of forsterite and Mg ferrite.

156. R. E. Birch and F. A. Harvey, "Forsterite and Other Magnesium Silicates as Refractories," *Jour. Amer. Ceram. Soc.*, **18** [6] 176–92 (1935).—In a survey of Mg silicates, studies were made of talc, serpentine, and olivine and mixtures of these and MgO. Forsterite ($2MgO \cdot SiO_2$) is the only Mg silicate stable above 1562°C. (2844°F.); hence the refractory should be chiefly forsterite. Such a refractory was made by enriching a low-Fe magnesian olivine with MgO. The MgO served to convert certain accessory minerals, such as talc and serpentine, to forsterite. The forsterite refractory withstood exceptionally high temperatures under load before failure. Full data are given.

157. F. Reinhart, "Magnesium Orthosilicate as a Refractory Building Material," *Tonind.-Ztg.*, **56** [23] 323–24 (1932).—Magnesium orthosilicate withstands high temperatures and the attack of fused compounds. It has properties similar to those of Al_2SiO_5 and may be used for furnace linings.

158. Luise Pieper, "New Refractory Materials from German Serpentines," *Ber. Deut. Keram. Ges.*, **18** [2] 41–64 (1937).—The phase rule of the system MgO–SiO_2–Fe_2O_3 is discussed. The occurrence of several deposits of serpentine is described. Forsterite bodies fired at cones 14 to 15 (1390° to 1410°C. (2534° to 2570°F.)) were prepared by admixture of the quantity of $MgCO_3$ and mineralizer required to form $2MgO \cdot SiO_2$ and $MgO \cdot Fe_2O_3$ from the decomposition of fayalite. Chemical, physical, and microstructural properties of the products are described. The materials have a refractoriness between those of SiO_2 and magnesite brick and have a relatively large thermal expansion of 0.6% between 100°C. (212°F.) and 700°C. (1292°F.). An experimental pressed brick made by mixing coarsely crushed raw serpentine with a finely ground mixture of serpentine, caustic burned $MgCO_3$, and 2% MgF_2 as mineralizer was fired at cone 15 (1410°C. (2570°F.)). The product was an excellent refractory with firing shrinkage 4.7%, porosity 21.5%, density 2.3, and temperature of initial collapse 1620°C. (2948°F.). The presence of $2MgO \cdot SiO_2$ and $2FeO \cdot SiO_2$ was pronounced, both on the surface and within the serpentine grains. It is not necessary to preform the required phases by the expensive process of mixing and calcination. The $MgCO_3$, however, must be precalcined to reduce the firing shrinkage.

159. G. Malquori, V. Sollazzo, and A. Giannone, "Forsterite Refractories from Serpentine and Magnesite," *Ricerca Sci.*, Ser. II, Year 9, II [9–10] 615–19 (1938).—A typical Italian serpentine contains SiO_2 38.53, Al_2O_3 3.81, Fe_2O_3 6.80, FeO 1.51, MgO 34.30, CaO trace; loss on fusion 14.58%, not determined 0.47%, melting point 1530°C. (2786°F.). When this serpentine, roasted at 900°C. (1652°F.), is mixed with MgO and H_2O to a thick paste, the melting point is raised: 10% MgO, 1740°C. (3164°F.); 20%, 1780°C. (3236°F.); 30%, 1790°C. (3254°F.); 40% 1800°C. (3272°F.); 60%, 1865°C. (3389°F.). The MgO was made by heating, in a muffle, magnesite of the following composition: MgO 41.51, CaO 2.26, R_2O_3 1.21, and SiO_2 2.15; loss on heating was 52.87%. By heating the mixture at 1100° to 1300°C. (2012° to 2372°F.) the amount of free MgO diminished because of compound formation. With 10% MgO there was no free MgO after 12 hr. at 1100°C. (2012°F.); with 30% MgO, 15% free MgO was found after 16 hr. at 1300°C. (2372°F.). Addition of 1.5% $MgCl_2$-H_3BO_3 to act as flux had little effect on the rate of combination.

160. V. M. Tsynkina, "Krasnodar Serpentinite as a Raw Material for the Production of Forsterite Refractories," *Ogneupory*, **6** [12] 1682–90 (1938).—The composition of the material was SiO_2 40.40, TiO_2 0.09, CO_2 0.92, Al_2O_3 1.17, Cr_2O_3 0.37, Fe_2O_3 4.50, FeO 2.10, NiO 0.14, MnO 0.14, CuO 0.04, CaO trace, MgO 38.56, Na_2O 0.05, K_2O 0.11, Li_2O 0.013, H_2O 11.59%, and SO_3 trace. The apparent porosity was 1.6 to 6.8%, water absorption 0.6 to 2.8%, volume weight, 2.46 to 2.64 gm. per cc., specific gravity 2.649, and refractoriness 1550°C. (2822°F.). The maximum porosity was at 800° to 900°C. (1472° to 1652°F.). A considerable increase in density took place only at 1300° to 1400°C. (2372° to 2552°F.). The batch was prepared with the use of magnesite mostly in the form of metallurgical powder. Samples pressed at 500 to 550 kgm. per sq. cm. were dried and fired at 1600°C. (2912°F.) in 6 hr. The most favorable magnesite content was 15 to 20%, but for resistance to basic open-hearth slag the magnesite should be increased to 20 to 25%. The properties were as follows: failure under a load of 2 kgm.

per sq. cm., starting at 1630° to 1640°C. (2966° to 2984°F.) and ending at 1660°C. (3020°F.); refractoriness 1790° to 1825°C. (3254° to 3317°F.); porosity 25 to 30%; crushing strength 360 to 500 kgm. per sq. cm.; resistance to spalling 4 to 10 coolings. The resistance to basic open-hearth slag is higher than that of silica brick. The use of serpentine without preliminary firing gave poor results. Firing in rotary kilns was the most expedient. About the same data were obtained with a trial lot of brick prepared from the same material, whether briquetted or not. Serpentine can probably be used instead of dunite in chromite refractories.

161. Ya. Klyucharev, "Fused Magnesia, Its Use as a Refractory," *Trudy Vsesoyuz. Nauch.-Issledovatel. Inst. Keram.*, No. 47, 72 pp. (1935); abstracted in *Referat. Silikatliteratur*, **3**, 3105 (1936).—Mixes of fused MgO and quartz (forsterite), unfired mixes, and mixes of fused MgO with a fused MgO bond, water glass, and Sorel cement were studied. The brick were fired to 1580°C. (2876°F.) and 1610°C. (2930°F.). Comparative tests with dead-burned magnesite brick showed that fused MgO brick withstood 14 to 27 chilling tests while the former averaged only 5. Magnesia-silica brick showed no softening at 1750°C. (3182°F.) under load.

162. A. V. Tereshchenko and O. M. Margulis, "Talc-Magnesite Refractories," *Ukrain. Nauch.-Issledovatel. Inst. Ogneuporov & Kislotouporov*, No. 44, pp. 118–20 (1938).—Talc-magnesite brick contains forsterite 85, spinel 5, periclase 5, and hematite and magnesite 5%. It has a refractoriness of 1780°C. (3236°F.), mechanical strength 200 to 250 kgm./sq. cm., incipient deformation under load 1550°C. (2822°F.), and porosity 22 to 28%. The brick is resistant to basic and iron slag.

163. D. P. Grigor'ev, "Coloring Different Synthetic Silicates with Nickel," *Zapiski Vserossiĭskogo Mineral. Obshchestva*, **67** [1] 63–66 (1938); abstracted in *Chem. Zentr.*, **1939, II**, 1455.—Synthetic forsterite containing up to 4.88% Ni, enstatite containing up to 4.74% Ni, and amphiboles (of the tremolite type) containing up to 4.94% Ni were obtained. The melting was carried out at 1500°C. (2732°F.) with an addition of 2 to 4% boric acid. Orthosilicates were green; silicates with a chain structure were yellow.

164. Friedrich Rinne, "Observation and X-ray Investigation Concerning the Rearrangement and Decomposition of Crystal Structures," *Z. Krist.*, **59**, 230–48 (1924).—Observations were made of the crystal structure for the isomorphous series forsterite, fayalite, etc.

165. A. G. Marants, "Magnesite Brick with Forsterite Binding," *Ogneupory*, **6** [10] 1507–18 (1938).—The following batch is recommended: 85% fired magnesite containing not under 90% MgO, 14.7 to 14.5% talc-carbonate rock (or other minerals such as dunite, serpentine, etc.), and 0.3 to 0.5% refractory clay. The manufacturing process is the same as that for ordinary magnesite brick. The grains of fired magnesite must be not larger than 0.75 to 1.0 mm.; talc rock and clay must pass a 70-mesh screen. The pressing must be done at 700 to 800 kgm. per sq. cm. and the firing at 1540° to 1560°C. (2804° to 2840°F.). The addition of talc rock increases the strength under load at high temperatures, the temperature of the beginning of deformation increasing 70° to 80°C. (158° to 176°F.) (1600° to 1620°C. (2912° to 2948°F.)) and the end 120° to 160°C. (248° to 320°F.) (1680° to 1700°C. (3056° to 3092°F.)). Brick made as above in an electric furnace were as good as ordinary magnesite brick.

166. See reference No. 175, this page.

167. A. Lévy, *Ann. Phil.*, [2]**7**, 61 (1824); from Mellor,* Vol. 6, p. 384.—The mineral forsterite was first described by L. in 1824. It was named after L. Forster. The mineral was found as crystals and crystal aggregates in Vesuvian lava.

168. J. J. Ebelmen, "A New Pyro Method for Obtaining the Combination of Crystals," *Ann. Chim. Phys.*, [3]**33**, 34–74 (1851); from Mellor,* Vol. 6, p. 384.—E. synthesized crystals of forsterite by using a mixture of boric acid, silica, and magnesia. The boric oxide simply served as a solvent of relatively low melting point, and it was evaporated by a protracted heating at a high temperature.

169. G. Lechartier, *Compt. Rend.*, **67**, 41 (1868); from Mellor,* Vol. 6, p. 384.—L. prepared forsterite by fusing silica and magnesia along with calcium chloride.

170. P. Hautefeuille, "Reproduction of Titaniferous Minerals," *Ann. Chim. Phys.*, [4]**4**, 129–76 (1865); from Mellor,* Vol. 6, p. 384.—H. prepared forsterite by fusing silica and magnesia along with magnesium chloride.

171. S. Meunier, *Compt. Rend.*, **93**, 737 (1881); from Mellor,* Vol. 6, p. 384.—M. prepared forsterite by heating it to redness in a mixture of steam and silicon chloride.

172. N. G. Sefström, *Jour. tech. ökon. Chem.*, **10**, 145 (1831); from Mellor,* Vol. 6, p. 384. See reference No. 218, p. 290.

173. W. A. Lampadius, *Jour. Mines*, **18**, 171 (1805); from Mellor,* Vol. 6, p. 384.

174. J. A. Hedvall, "Reactivity in Solid State of Silica with Oxides of Calcium, Barium, and Magnesia," *Z. Anorg. Chem.*, **98**, 57–69 (1916); from Mellor,* Vol. 6, p. 384.

175. P. Berthier, *Ann. Chim. Phys.*, [2]**24**, 376 (1823); from Mellor,* Vol. 6, p. 384.—In references Nos. 172 to 175, the authors heated various mixtures of magnesia and silica and obtained more or less devitrified enamels.

176. J. W. Cobb, "Synthesis of a Glaze, Glass, or Other Complex Silicate: II–IV," *Jour. Soc. Chem. Ind.*, **29**, 250–59, 335–36, 399–404 (1910); from Mellor,* Vol. 6, p. 384.—C. noted that the reaction between magnesia and silica begins below the melting point of either component.

177. W. Pukall, *Silikat Z.*, **2**, 74 (1914); from Mellor,* Vol. 6, p. 384.—P. obtained forsterite by heating an intimate mixture of magnesia and silicic acid. This product gained only 2.58% after lying in water for 70 days.

178. G. Stein, "Preparation of Some Silicates," *Z. Anorg. Chem.*, **55**, 159–74 (1907) (p. 166); from Mellor,* Vol. 6, p. 384.—S. fused a mixture of magnesia and silica at a temperature exceeding 2000°C. (3632°F.) in an electrically heated carbon tube furnace and obtained crystals of forsterite. See reference No. 250, p. 292.

179. E. T. Allen, F. E. Wright, and J. K. Clement, "Minerals of the Composition $MgSiO_3$; a Case of Tetramorphism," *Amer. Jour. Sci.*, [4]**22**, 385–438 (1906); from Mellor,* Vol. 6, p. 385.—The crystals of forsterite are decomposed by HCl with the separation of gelatinous silica.

PATENTS

180. Henri Herrenschmidt, "Artificial Silicates of Magnesia," Brit. 20,378, Sept. 24, 190[illegible].—The process of manufacturing artificial silicates of magnesia comprises fusing the mixtures 65% SiO_2 and 35% MgO and 70% MgO and 30% SiO_2 in an electric furnace.

181. A. Marks, "Magnesite Refractory and Method of Making," U. S. 1,616,055, Feb. 1, 1927.—Dead-burned magnesite ground to pass through a 20-mesh screen was mixed thoroughly with 3.5 to 8.5% linseed oil or other vegetable oils having reactive properties and was then pressed into brick. These brick were dried and were then fired at 1400° to 1500°C. (2552° to 2732°F.). Comparative petrographic studies of water-bonded and oil-bonded brick showed that the forms were made up of periclase grains about 0.15 mm. in diameter cemented with forsterite and monticellite. The individual grains were saturated with iron oxide and were firmly cemented together into aggregate groups; the groups or aggregated grains, however, were not so well bonded, and the brick was somewhat friable. The oil-bonded brick were made up of periclase grains about 0.04 mm. in diameter. The iron oxide was much less and existed as minute specks of magnesioferrite within the grains of periclase. The individual grains and groups of grains were cemented together with forsterite and monticellite. These brick

* J. W. Mellor, Comprehensive Treatise on Inorganic and Theoretical Chemistry. Longmans, Green & Co., Ltd., London, 1925.

had a finer, denser, and better cemented texture than the water-bonded brick.

182. JOHN D. SULLIVAN (Battelle Memorial Institute), "Fused Refractory Products," U. S. 2,113,818, April 12, 1938.—Oxides of Mg, Si, and Fe are melted together with the MgO in such a preponderate proportion that the Fe oxide will be in solid solution and no silicate less basic than the orthosilicate will be present.

183. G. E. SEIL (E. J. Lavino & Co.), "Corrected Magnesia Refractories," Brit. 487,213, June 16, 1938; Can. 375,117, July 12, 1938; Fr. 832,283, Sept. 23, 1938; Ital. 358,921, May 6, 1938; U. S. 2,206,131, July 2, 1940.—To 100 parts by weight of dead-burned crystallized magnesia (ground to pass a 6-mesh screen) of the chemical composition MgO 90.80, Fe_2O_3 1.02, Al_2O_3 0.37, SiO_2 5.34, and CaO 2.23%, 14 parts by weight of finely divided silica (ground to pass a 100-mesh screen) are added. These materials are mixed together, tempered, and pressed into brick which are dried and then fired at a temperature between 1704° and 1900°C. (3100° and 3450°F.). By this method, a refractory body is produced which has approximately the following chemical analysis, MgO 78.24, Fe_2O_3 2.62, Al_2O_3 0.79, SiO_2 16.12, and CaO 1.93%, and the following petrographic analysis, periclase 58.01, magnesium orthosilicate 32.90, and monticellite 5.38%. The magnesium orthosilicate was physically located in such a way that a structural network of magnesia as a base or grog, each grain of which is completely surrounded by an adhering mixture of magnesium orthosilicate and monticellite, was produced. Physical tests carried out on (*A*) these brick in comparison with (*B*) those of a uniform mixture of periclase and magnesium orthosilicate show that spalling losses in a standard dry panel spalling test at 1370°C. (2500°F.) are 26.6 and 40.6%, respectively. Brick *A* did not fail under a load of 25 lb. per sq. in. at 1649°C. (3000°F.), but brick *B* failed at 1645°C. (2993°F.). Subsidence under their own weight standing on end after 5 hr. at 1593°C. (2900°F.) was 0.34% for brick *A* and 1.17% for brick *B*.

184. BORGESTAD FABRIKKER, "Ceramic or Refractory Material," Brit. 260,298, Oct. 24, 1925.—A composition for making refractory articles or for cement for binding other refractory materials is prepared by heating to 1000° to 1400°C. (1832° to 2552°F.) a mixture of MgO and talc proportioned to form Mg orthosilicate, with or without fillers, such as olivine or Mg orthosilicate or similar silicates.

185. V. M. GOLDSCHMIDT AND R. KNUDSEN, "Ceramic Material," Can. 271,177, May 21, 1927.—A ceramic product comprises artificial Mg. The orthosilicate together with Mg silicates contains less silica in proportion to MgO than does the orthosilicate.

186. BORGESTAD FABRIKKER, "Ceramic Material," Fr. 34,049, Sept. 14, 1927; Addition to 623,573.—A ceramic material is made from particles of natural olivine rock agglomerated with Mg orthosilicate obtained artificially, e.g., from talc and magnesite. The olivine rock may be replaced partially or wholly by particles of Mg orthosilicate.

187. G. KNUDSEN, V. M. GOLDSCHMIDT, AND R. KNUDSEN, "Refractory Building Material, etc.," Brit. 307,391, Sept. 3, 1927.—In making a product consisting substantially of Mg orthosilicate, as described in Brit. 260,298 (see reference No. 184), the talc is wholly or partly replaced by other Mg hydrosilicates, such as serpentine, in forming the reaction mixture. Various materials may be added; details of procedure are given.

188. V. M. GOLDSCHMIDT AND R. KNUDSEN, "Use of Natural Olivine Rock for Furnaces or Other Apparatus Exposed to High Temperatures or to Chemical Action," Brit. 283,791, June 22, 1927; Can. 285,503, Dec. 11, 1928.—Solid pieces may be used or smaller pieces may be agglomerated with a binder such as colloidal Mg silicate, MgO, $Mg(OH)_2$, talc, lime, clay, or bituminous material.

189. METALLGES. A.-G., "Refractory Materials," Brit. 340,487, Sept. 23, 1929 (Oct. 23, 1928).—A material retaining substantially the same volume when fired is formed by mixing, in granular form, Mg silicates which expand when fired, such as olivine, with powdered mixtures of Mg silicates and substances rich in Mg, such as magnesite, which contract when fired; an organic binder such as sulfite cellulose lye may also be added, and the composition may be molded under pressure and fired at a temperature suitable for the formation of Mg orthosilicate.

190. METALLGES. A.-G., "Refractory Materials," Brit. 337,605, Dec. 24, 1930 (Nov. 7, 1929).—Mg silicate materials such as olivine, serpentine, or talc containing Fe are heated, without fusion, with substances rich in Mg, such as MgO or magnesite, in an oxidizing atmosphere for the conversion of the Fe present into Mg ferrite and of the free SiO_2 into Mg orthosilicate. Materials containing Ni, Mn, Cr, and Al may be similarly treated; numerous details and examples are given.

191. V. M. GOLDSCHMIDT AND ROLF KNUDSEN (Borgestad Fabrikker), "Ceramic Material (Artificially Produced Magnesium Orthosilicate)," U. S. 1,756,786, April 29, 1930.—The material is obtained by firing a mixture of talc and MgO so that all is converted to $2MgO \cdot SiO_2$.

192. V. M. GOLDSCHMIDT (R. Knudsen, co-inventor), "Refractory Compositions," Ger. 583,194, Aug. 31, 1933.—Compositions consisting mainly of Mg orthosilicate are prepared by heating talc with MgO or magnesite to a temperature insufficient to fuse the mixture, e.g., to 1300° to 1450°C. (2372° to 2642°F.). Natural Mg orthosilicate may be added to the initial mixture.

193. V. M. GOLDSCHMIDT AND K. SIEDENTOPF (Metallges. A.-G.), "Highly Refractory Products Suitable for Use in Brick Form," U. S. 1,926,094, Sept. 12, 1933.—Coarse granular natural products rich in Mg orthosilicate, such as olivine, are mixed with finely ground material consisting of natural products rich in Mg orthosilicate and of substances rich in Mg, such as magnesite; the mixture is fired to produce a highly refractory product substantially free from troublesome changes in volume. The firing is conducted by heating to temperatures sufficiently high to effect cohesion of the particles while avoiding melting.

194. F. A. HARVEY AND R. E. BIRCH, "Magnesia Refractory," U. S. 2,026,088, Dec. 31, 1935.—Refractory brick are made from a mixture of (1) dead-burned magnesite, 85%, of the following approximate chemical composition, MgO 85, Fe_2O_3 5, SiO_2 4, and undetermined 6%, ground to pass a 3-mesh screen, and olivine, 15%, ground to pass a 70-mesh screen; or (2) 90% dead-burned magnesite and 10% serpentine or an artificial forsterite composition. The two ingredients are ground together to pass through a 20-mesh screen. In either case the ingredients are thoroughly mixed with 5% water, pressed, dried, and then fired in a kiln furnace at temperatures as high as 1600°C. (2912°F.). The product obtained is made up of a granular basic refractory bonded by 5 to 50% crystalline forsterite.

195. R. H. YOUNGMAN (Harbison-Walker Refractories Co.), "Refractory Material," Brit. 317,449, Aug. 16, 1928.—Serpentine is made suitable for use as a refractory material by calcining it at about 1600°C. (2912°F.) to drive off volatile constituents and reduce its porosity below 20%. The calcined material may be ground and molded into brick after admixture with "lignum liquor" or water and may be fired at about 50°C. (122°F.) below the calcining temperature. Magnesite may be added to vary the properties of the product.

196. F. A. HARVEY AND R. E. BIRCH (Harbison-Walker Refractories Co.), "Refractory Mortar Suitable for Resisting High Temperatures," U. S. 2,077,793 to 2,077,796, April 20, 1937.—A forsterite refractory is prepared by grinding forsterite material to form coarse granules and mixing the latter with magnesia-rich material containing lime, 3 to 30%, in an amount sufficient to provide at least about 0.8% but not over about 8% of lime.

197. F. A. HARVEY AND R. E. BIRCH (Harbison-Walker Refractories Co.), "Refractory Mortar Suitable for Resisting High Temperatures," U. S. 2,077,296, April 20, 1937.—A refractory material contains at least about 50% of chrome ore, at least 10% of olivine, and magnesite in an amount $^1/_4$ to 4 times the quantity of the olivine.

198. V. M. GOLDSCHMIDT, "Refractory Compositions," Ger. 677,322, June 23, 1939.—Chromite (50 to 90 parts) is mixed with a material containing a high proportion of Mg orthosilicate, e.g., olivine (10 to 40 parts), and the mixture, optionally after molding, is fired, e.g., at 1430°C. (2606°F.). Either or both of the materials may first be calcined or sintered. Up to 50% of the chromite may be replaced by MgO. Preferably, the chromite is used in the form of coarse granules, while the MgO and the silicate are taken in finely divided form. Examples and various details are given.

199. ÖSTERREICHISCH AMERIKANISCHE MAGNESIT A.-G., "Refractory Products," Fr. 837,165, Feb. 3, 1939.—Brick are made from a mixture of chromite with a minor portion of MgO. Most of the MgO is introduced into the mixture in finely divided form. The presence of finely divided chromite is avoided. Grains 0 to 0.1 mm. in diameter are removed from a crushed mass of chromite ore containing grains 0 to 3.0 mm. in diameter. The mass is then mixed with finely powdered magnesite, and a small amount of sulfite waste liquor is added to the mixture as a binder. The mixture is molded, dried, and fired at 1400° to 1600°C. (2552° to 2912°F.).

200. A. H. BEALE AND E. F. MCDOWELL, "Facing Compound for Steel Furnaces," U. S. 850,723, April 9, 1907.—The compound contains chrome ore 70, magnesite 30, and a binder, such as anhydrous pitch or tar, 20 parts by volume.

201. G. E. SEIL, "Chromite Refractory Materials," U. S. 2,028,018, Jan. 14, 1936; Belg. 396,089, June 30, 1933; Can. 335,266, Aug. 29, 1933; Fr. 755,038, Nov. 18, 1933; Ital. 314,924, Feb. 9, 1934; Brit. 409,130, April 26, 1934.—A refractory product of chromite, in which the gangue of low melting point has been transformed into a refractory material, is made by intimately mixing the chrome ore and crystallized MgO highly calcined, the MgO being present in amount above 12.5% (preferably 17 to 25%) of the total weight of the mixture, grinding and kneading the mixture, and molding and calcining the mass, probably to about 1650°C. (3002°F.).

202. G. E. SEIL, "Method of Making Chromite Refractories," U. S. 2,037,600, April 14, 1936.—Natural chrome ore is ground to form coarse granules and is mixed with dead-burned MgO in finely divided form and in a proportion of over 13.5% but insufficient to decompose the chromite spinel of the ore; the mixture is fired to produce a product of substantially higher softening point than that of a product similarly formed without the use of MgO.

203. G. E. SEIL (E. J. Lavino & Co.), "Process of Making Chromite Refractories," U. S. 2,060,697, Nov. 10, 1936; Belg. 417,817, Oct. 8, 1936; Ital. 345,818, Jan. 16, 1937; Fr. 811,670, April 20, 1937; Can. 366,039, May 11, 1937; Brit. 468,659, July 9, 1937.—In making a fired chromite refractory from natural chrome ore of a substantially high softening point due to the conversion of at least a substantial portion of the low-melting gangue into a refractory material without decomposition of the chromite spinel of the ore, chrome ore is heat-treated in the presence of $Mg(OH)_2$, dead-burned magnesite, or a magnesium salt such as $MgCO_3$, furnishing MgO after ignition, at a temperature at least equal to the firing temperature of the refractory (the Mg salt being present in an amount sufficient to furnish MgO to convert at least a substantial portion of the low-melting gangue into forsterite but insufficient to decompose the chromite spinel of the ore), a portion of the treated ore is ground to relatively coarse granules, another portion is ground to relatively fine granules, and a suitable mixture of the fine and coarse material is tempered with water and is shaped and fired.

204. W. M. FARNSWORTH, "Refractory Material Suitable for Lining and Patching Electric Furnaces, etc.," U.S. 2,033,886, March 10, 1936.—Olivine 2, chrome ore about 1, and calcined magnesite about 3 parts are used together.

205. G. E. SEIL, "High Temperature Refractory Cement," U. S. 20,413, June 15, 1937; reissue of original U. S. 2,042,363, May 26, 1936.—Refractory cement which will withstand up to 1927°C. (3500°F.) is formed of 72 parts of heat-treated recrystallized chrome ore ground to pass through a 40-mesh screen, 21 parts of ground periclase, 5 parts of water-soluble sodium silicate, and 2 parts of starch. If oil is used instead of water, then 0.1% rosin will replace the starch. These materials are mixed together until they form a uniform mixture. The ultimate material (after firing) will be made of chromite and forsterite.

206. G. C. FLUDDER, G. E. FLUDDER, AND A. W. FLUDDER, "Refractory Material for Brick," U. S. 976,996, Nov. 29, 1910.—Refractory material for brick, etc., is made by agglomerating a mixture of SiO_2 or alumina, magnesite, or chrome ore (with or without Mg silicate) with $Al_2(SO_4)_3$ and hot H_2O and then firing.

207. H. G. TURNER, "Material for Furnace Linings," U. S. 785,841, March 28, 1905.—Magnesite is melted in an electric furnace, cooled, and finely ground. The powder produced is mixed with about 2% of a material, such as boric acid, borax, $MgCl_2$, or water glass, which will act as a binding agent. The mixture is made into a paste with water and applied as a coating to the furnace lining, or the mixture may be moistened with water, pressed into brick, and fired in a suitable kiln. A highly refractory material of crystalline MgO is obtained.

208. ARTHUR SPRENGER, "Refractory Mass," Ger. 667,691, Nov. 18, 1938; Cl. 80b. 8.04.—Fireproof chromite stone is made from a paste of ground Cr ores containing the oxides FeO and MgO and the oxides Cr_2O_3 and Al_2O_3 in proportions as nearly equimolecular as possible and containing less than 3% of SiO_2. In an example, the starting material is a Cr ore containing 51.8 Cr_2O_3, 13.5 Al_2O_3, 5.4 Fe_2O_3, 13.3 FeO, 13.2 MgO, and 1.2% of SiO_2, MnO, and CaO.

209. G. E. SEIL (E. J. Lavino & Co.), "Refractory Brick Suitable for Use in Furnace Construction," U. S. 2,170,254, Aug. 22, 1939.—A body such as a fire-clay brick is provided with a dried but unfired, waterproof, and cementatory adhering coating including a water-insoluble base, such as chrome ore and periclase.

Monticellite

210. PAUL HERMANN, "Investigations on the Melting of Orthosilicates," *Z. deut. geol. Ges.*, **58**, 396–404 (1906).—A series of mixtures of Ca and Mg orthosilicates at intervals of 6% made from pure chemicals in graphite crucibles were prepared and studied optically. H. suggests that "dusting" is due to volume change or inversion. Day, Shepherd, and Wright (see reference No. 22, p. 275) are referred to. Dusting ceases beyond 18.5% $2MgO \cdot SiO_2$. Fifty per cent of the mix contained only monticellite and glass. Some very interesting considerations on the velocity of crystallization are included. A curve is obtained with two very marked maxima, one at the composition of monticellite and one at 68.75% $2MgO \cdot SiO_2$, when mixed crystals and forsterite are in equal quantities. The curve is based on the assumption of H. that velocity of crystallization is proportional to the volume of the crystals when the conditions of cooling are the same. Illustrated.

211. J. B. FERGUSON AND H. E. MERWIN, "VII, Ternary System CaO–MgO–SiO_2," *Amer. Jour. Sci.*, [4]48, 81–123 (1919).—Charges of known composition, made up of chemically pure $CaCO_3$, MgO, and SiO_2, were thoroughly mixed in a mortar, fused in platinum crucibles, and reduced to a fine powder. This procedure was repeated 2 or 3 times to insure complete homogeneity in the final product. Crystals of monticellite were obtained from 5 quenches at temperatures between 1400°C. (2552°F.) and 1500°C. (2732°F.), having compositions ranging from 33 to 37 CaO, 21 to 28 MgO, and 39 to 42 SiO_2. The crystals appeared as equant grains without facets. The phase

$CaO \cdot MgO \cdot SiO_2$ is unstable at its melting point, and in addition it is variable in composition since it belongs to a series of solid solutions of forsterite in pure monticellite. The limit would be about 10% forsterite or corresponding to the composition CaO 32, MgO 28.75, and SiO_2 39.25. Attempts to prepare pure monticellite did not succeed; instead, a mixture of crystals of alpha-$2CaO \cdot SiO_2$ and crystals of monticellite solid solution was always obtained. See reference No. 63, p. 279.

212. Nelson W. Taylor and Francis J. Williams, "Reactions Between Solids in the System CaO–MgO–SiO_2 in the Temperature Range 600° to 1200°C. (1112° to 2192°F.)," *Bull. Geol. Soc. Amer.*, **46** [7] 1121–36 (1935).—All the anhydrous compounds in the system except merwinite were prepared by heating mixtures of $CaCO_3$, $MgCO_3$, and quartz at 600°C. (1112°F.), 800°C. (1472°F.), 1000°C. (1832°F.), and 1200°C. (2192°F.) for 20 hr. X-ray examination was used for identification. MgO crystallized readily at low temperatures while CaO did not. MgO also replaced CaO in silicates. The mineral phases formed were determined more by diffusion mechanism than by equilibrium factors. CaO-SiO_2 mixes reached equilibrium more easily than the MgO-SiO_2 mixes. The order of ease of formation of the various solids agrees with field observations of thermal metamorphism.

213. D. S. Belyankin, K. M. Fedot'ev, and C. S. Nikogosyan, "Experimental Studies of Magnesium Iron-Bearing Monticellites," *Neues Jahrb. Mineral. Geol., Beilage Bd.*, **68**, 337–47 (1934).—Artificial monticellites were made of the composition $2CaO \cdot SiO_2$, where the second portion of the molecule comprises successively 100, 67, 49, 29, and 7% $2MgO \cdot SiO_2$. Their liquidus temperatures and optical properties were determined.

214. G. B. Brown and J. West, "Structure of Monticellite ($MgO \cdot CaO \cdot SiO_2$)," *Z. Krist.*, **66**, 154–61 (1927).—The space lattice is studied.

215. D. Belyankin and B. Ivanov, "System of Monticellite," *Amer. Jour. Sci.*, [5]**22**, 72–80 (1931).—The average refractive index of monticellite ($^1/_3$ of alpha + beta + gamma) rises steadily and regularly with increases of Fe and Mn. The birefringence (gamma-alpha) is small for varieties rich in MgO (0.015 to 0.017) but increases rapidly to 0.050 for Fe-rich varieties. Although not a straight line, $2V$ decreases with increase of Fe and Mg.

216. J. W. Mellor, Comprehensive Treatise on Inorganic and Theoretical Chemistry: Vol. 6, p. 408. Longmans, Green & Co., Ltd., London, 1925.—The very rare mineral monticellite was named after T. Monticelli; it was found in yellowish crystals at Mount Vesuvius. The mineral belongs to the olivine family which includes forsterite, fayalite, and tephroite.

217. H. J. Brooke. *Phil. Mag.*, [1]**10**, 265 (1831); from Mellor,* Vol. 6, p. 408.—The crystals of monticellite were first described by B. in 1831.

218. N. G. Sefström, *Jour. tech. ökon. Chem.*, **10**, 145 (1831); from Mellor,* Vol. 6, p. 408.—S. obtained a glass of the composition of magnesium calcium orthosilicate by fusing the constituents together. See reference No. 172, p. 287.

219. V. Pöschl, "Experimental Investigations on Isomorphous Silicates," *Tschermak's mineralog. & petrog. Mitt.*, [2]**26**, 413–56 (1907) (p. 442); from Mellor,* Vol. 6, p. 408.—P. prepared products containing monticellite by fusing the component silicates.

220. J. Morozewicz, *Tschermak's mineralog. & petrog. Mitt.*, [2]**18**, 191 (1899); from Mellor,* Vol. 6, p. 408.—M. prepared products containing monticellite by fusing the component silicates.

221. V. S. Deleano, "Fusion Experiments on Calcium and Magnesium Silicates," *Z. Anorg. Chem.*, **84**, 401–30 (1914); from Mellor,* Vol. 6, p. 408.—D. studied the fusion curves of mixtures of magnesium and calcium orthosilicate and found that a eutectic is produced at 1400°C. (2552°F.) with about 80% of magnesium orthosilicate. No monticellite was formed, and it was assumed that the occurrence of this mineral in volcanic products shows that a mineralizer was present. Mixtures rich in calcium orthosilicate disintegrate on cooling. Enstatite is formed, and the disintegration of calcium orthosilicate occurs in the presence of up to 50% of enstatite.

222. See reference No. 210, p. 289.

223. G. Tschermak, *Sitzber. Akad. Wiss. Wien*, **115**, 221 (1906); from Mellor,* Vol. 6, p. 409.—T. found that when monticellite is treated with acids orthosilicic acid separates out.

224. W. Suida, *Sitzber. Akad. Wiss. Wien*, **113**, 736 (1904); from Mellor,* Vol. 6, p. 409.—S. found that the mineral is feebly stained by basic aniline dyes.

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* J. W. Mellor, Comprehensive Treatise on Inorganic and Theoretical Chemistry. Longmans, Green & Co., Ltd., London, 1925.

Merwinite

225. E. S. Larsen and W. F. Foshag, "Merwinite, a New Calcium Magnesium Orthosilicate from Crestmore, California," *Amer. Mineralogist*, **6**, 143–48 (1921).—Merwinite has characteristic optical properties with high relief, moderate birefringence, and polysynthetic twinning. The mineral is colorless to very pale greenish and has a vitreous luster. The mixture has a light greenish to grayish color and a somewhat greasy luster. It dissolves quickly and completely in HCl and, upon evaporation, gelatinizes perfectly. The compound $3CaO \cdot MgO \cdot 2SiO_2$ does not appear in any of the lime–magnesia–silica systems which have been studied. Merwinite is, therefore, probably a low temperature form, breaking down before its melting point is reached. Its association with wollastonite indicates that it crystallizes below a temperature of 1190°C. (2174°F.), the inversion temperature of wollastonite. Its occurrence in rocks of pneumatolytic contact metamorphic origin indicates a temperature much lower still.

226. J. Phemister, "Summary of Progress of Geological Survey of Great Britain for 1937–1938," 109 pp. Petrographical Department, pp. 86–87.—Merwinite was found in a sample of blast-furnace slag as an essential constituent. It is triclinic and has a somewhat higher birefringence than the naturally occurring mineral.

PATENTS

227. H. C. Lee (Non-Metallic Minerals, Inc.), "Merwinite Refractories," Can. 358,403, June 9, 1936.—Dolomite (400 parts by weight) and silica sand (83 parts by weight), proportioned to give 1.4 parts of lime for each part, by weight, of silica, are ground in a ball mill with water until a substantial portion passes a 200-mesh screen. In slurry form it is fed to a rotary kiln fired at 1538°C. (2800° F.) to form a dense hard light brownish gray clinker; this is crushed to pass a 6-mesh screen, tempered with 6 to 8% water, pressed into brick, dried, and fired at cones 14 to 16 (1390° to 1450°C. (2534° to 2642°F.)). The product consists of crystals of merwinite intermixed with periclase. It withstands higher temperatures than fire-clay refractories, is resistant to open-hearth slags, has a lower thermal conductivity than magnesite refractories, and possesses slight hydraulic properties.

228. Non-Metallic Minerals, Inc., "Refractory Materials," Fr. 805,091, Nov. 10, 1936.—A refractory is made by heating CaO and SiO_2 in the proportions of 1 to 1.4 with MgO, which represents at least 12% of the mixture. The proportions are such that merwinite and periclase are obtained.

229. Non-Metallic Minerals, Inc., "Refractories," Fr. 47,446, May 5, 1937; addition to 805,091 (see preceding ref.); Brit. 475,508, Nov. 19, 1937; addition to 464,047, April 21, 1937.—An agent which will protect the merwinite against harmful reaction when it finally comes in contact with lime, e.g., oxy compounds of B, P, or Cr, is added to the mixture to be heated. The MgO is used in excess of that needed to produce merwinite.

230. H. C. Lee (Non-Metallic Minerals, Inc.), "Merwinite-Containing Refractories," U. S. 2,089,970, Aug. 17,

1937; Brit. 464,047 (see preceding ref.); Fr. 808,862, Feb. 17, 1937.—Refractories are made by heating materials having a basis of MgO, CaO, and SiO_2 to obtain a silicate binder which contains Ca and Mg and which is both a union or hydraulic setting agent at a low temperature and a crystalline union agent at high temperature; thus a magnesian clay and dolomite in proportions to give about a 1.6:1 ratio between CaO and SiO_2 are ground, intimately mixed into a paste, molded in the form of blocks, dried, and calcined. The calcined blocks are hard and dense and are composed of periclase, merwinite, and Ca orthosilicate. Examples are given of the use of sedimentary magnesite and limestone or dolomite and serpentine and dolomite.

231. H. C. Lee (Basic Dolomite, Inc.), "Lime-Resistant Refractories," Can. 371,285, Jan. 18, 1938.—Material containing CaO, MgO, and SiO_2 in proportions to form merwinite is fired, the product is crushed, and a solution of an agent, e.g., H_3BO_3, that protects merwinite against the action of lime is added. The material is then molded and fired.

Barium Orthosilicate

232. Pentti Eskola, "Silicates of Strontium and Barium," *Amer. Jour. Sci.*, [5]**4**, 331–75 (1922).—Mixtures were made of pure quartz, $CaCO_3$, $BaCO_3$, and $SrCO_3$. These substances were dried at 150°C. (302°F.) before weighing, mixed together, melted if possible, chilled, crushed, reheated, and ground twice more. The equilibrium relations were ascertained almost exclusively by the quenching method. *Eutectic $BaO \cdot SiO_2$–$2BaO \cdot SiO_2$:* A mixture of these compounds containing 75% BaO gave crystals of both kinds at 1546°C. (2815°F.), but at 1556°C. (2833°F.) it gave only crystals of $2BaO \cdot SiO_2$ and glass. From this it may be concluded that there is a eutectic at about 74.5% BaO with a melting point of 1551° ± 6°C. (2824° ± 10.8°F.). No other compounds except the two named above occur in this part of the system. *Barium orthosilicate, $2BaO \cdot SiO_2$:* Barium orthosilicate appears as a granular mass of rounded grains and does not show any cleavages or twinning. The melting point is higher than that of platinum. Alpha (D) = 1.810 ± 0.005; gamma (D) = 1.830 ± 0.005. *Barium oxide, BaO:* Mixtures of barium orthosilicate and barium oxide were not studied more closely. The fact that all the mixtures containing an excess of BaO over the orthosilicate ratio attack platinum seems to prove that they contain free BaO. See also reference No. 251, p. 292.

233. G. Grube and R. Truckseß, "Formation of Barium Silicates from Barium Carbonate and Silicic Acid in the Solid State," *Z. Anorg. & Allgem. Chem.*, **203** [1] 75–96 (1931).—In the manufacture of $Ba(OH)_2$ according to Deguide (Ger. 346,762 and 367,133) by heating $BaCO_3$ and SiO_2 and subsequently decomposing with water, the silicates presumably formed are $2BaO \cdot SiO_2$, $3BaO \cdot SiO_2$ (or a mixture of $2BaO \cdot SiO_2$ and BaO), and the silicate intermediate between these 2 when the ratio of $BaCO_3$:SiO_2 is 2:1, 3:1, and 2:3, respectively. A further increase in the $BaCO_3$ proportion is claimed to produce silicates of low melting point which attack the oven. The purpose of the present investigation was to establish the maximum number of molecules of $BaCO_3$ which can be combined with each molecule of SiO_2 in the solid state and to measure the pressure of equilibrium of CO_2 for each individual reaction step. According to the theory of Jacob (*Helv. Chim. Acta.*, **3**, 669–704 (1920)), $4BaO \cdot SiO_2$, $3BaO \cdot SiO_2$, $2BaO \cdot SiO_2$, and $BaO \cdot SiO_2$ should exist, but of these only the last two have been established (see references Nos. 232, p. 291, and 238, p. 292; *Z. Anorg. & Allgem. Chem.*, **163**, 1–30 (1927)). In a series of systematic experiments, thorough mixtures of finely ground pure $BaCO_3$ and SiO_2 were heated in a Pt crucible 5 to 50 hr. at 700° to 1100°C. (1292° to 2012°F.). Every 4 hr. the mixtures were cooled and reground. During the heating the crucible was closed, the cover being provided with a boring for a thermoelement extending into the mixture and an inlet tube for CO_2. *Conclusions:* The primary product of the reaction in the solid state is $BaO \cdot SiO_2$. This reacts further with $BaCO_3$ to form $2BaO \cdot SiO_2$ which, when all $BaCO_3$ is converted, reacts with the remaining SiO_2 to form $BaO \cdot SiO_2$. This peculiar course of reaction is explained by the theories and observations of Jander (*ibid.*) and Tammann (*ibid.*, **149**, 21–34 (1925)). Noteworthy was the observation in two of the experiments that, by employing reaction mixtures of the ratio $BaCO_3$:SiO_2 = 3:1 and 4:1 heated at 1100°C. (2012° F.) for 9 and 5 hr., respectively, the reaction mixture contained silicates with 2.31 and 2.28 molecules of BaO, respectively, for each molecule of SiO_2, i.e., products richer in BaO than $2BaO \cdot SiO_2$. A series of tensieudiometric measurements for the identification of these silicates was carried out with a tensieudiometer constructed according to the principle of Huttig (*ibid.*, **114**, 161–73 (1920)). The reaction velocity of the formation of $BaO \cdot SiO_2$ from $BaCO_3$ and SiO_2, the changes in the pressure of equilibrium of CO_2 at different temperature for the molecular mixtures (1) $BaCO_3 + SiO_2$, (2) $BaO \cdot SiO_2 + BaCO_3$, (3) $2BaO \cdot SiO_2 + BaCO_3$, and (4) $3BaO \cdot SiO_2 + BaCO_3$, and for pure $BaCO_3$, the tensieudiometric synthesis of $3BaO \cdot SiO_2$ and $4BaO \cdot SiO_2$, and the isobaric decomposition of $BaCO_3$ rendered proof that besides $BaO \cdot SiO_2$ and $2BaO \cdot SiO_2$, $3BaO \cdot SiO_2$ and probably $4BaO \cdot SiO_2$ are formed in the solid state. The course of the isobars for the two last compounds showed the formation of mixed crystals. From the measurements of the temperature and CO_2 pressure belonging to each reaction, (1) 690°C. (1274°F.), 760 mm.; (2) 800°C. (1472°F.), 760 mm.; (3) 970°C. (1778°F.), 50 mm.; and (4) 950°C. (1742°F.), 10 mm., the heat tones were calculated as 37, 42, 50, and 59 Cal., respectively. The heat tone for the decomposition of $BaCO_3$ is +51.70 Cal. By subtracting the latter from the heat tones of the above reaction mixtures, the following approximate heats of formation are obtained: $BaO \cdot SiO_2$ 26, $2BaO \cdot SiO_2$ 21, $3BaO \cdot SiO_2$ 13, and $4BaO \cdot SiO_2$ 4 Cal.

234. W. Jander, "Reactions in the Solid State at High Temperatures: IV, Reaction Between Basic and Acid Oxides and Carbonates and Method of Compound Formation," *Z. Anorg. & Allgem. Chem.*, **174** [1] 11–23 (1928).—When solid substances react, a reaction layer is first formed between the surfaces in contact, and further reaction only proceeds as one or both components diffuse through this layer. In the reaction between $BaCO_3$ and SiO_2, the reaction mixtures are heated from a few hours to 3 days at 950°C. (1742°F.). With an excess of $BaCO_3$ the principal product is the orthosilicate, while with an excess of quartz the metasilicate is the chief product. The results indicate that diffusion through the surface reaction layer is responsible for completion of the reaction, and this is made possible only by the solubility of one of the components in the compound formed in the reaction.

235. T. R. Lynam and W. J. Rees, "Chrome Refractories for Use in the Neutral Course of the Basic Open-Hearth Furnace," *Trans. Ceram. Soc.*, **37** [11] 481–505 (1938).—Increasing the MgO additions to a chrome batch to convert the serpentine to forsterite gradually increases the mechanical strength at high temperatures. The presence of ferruginous impurities in Grecian magnesite aids in the development of forsterite. Lime-bonded chrome shows no better mechanical strength than the chrome batch alone. $BaSO_4$ as a bond effects marked improvement. Lowest porosity and highest bulk density are obtained with hand-tamped specimens having a gradation of 45% coarse, 10% medium, and 45% fine particles. Slag resistance is best in the densest specimens. Coarser gradation gives the test specimens good resistance to spalling but also structural weakness. Gradations giving the densest

specimens do not produce the expected high mechanical strength, supposedly because of lack of bonding agent and low fabricating pressure.

236. M. Oyama, Y. Nakazi, and T. Nagami, "Steatite Bodies Containing BaO," *Electrotech. Jour.*, **2** [1] 22 (1938). —Bodies containing, in addition to steatite, from 5 to 33.3% BaO calculated on the amount of free silica, were fired to 1250° to 1400°C. (2282° to 2552°F.). They were resistant to moisture and gave good insulating material.

237. N. A. Toropov and P. F. Konovalov, "Solid Solutions of Calcium and Barium Orthosilicates," *Compt. Rend. Acad. Sci. U.R.S.S.*, **20**, 663–64 (1938) (in German). —The index of refraction and specific gravity are given for mixtures of $2CaO \cdot SiO_2$ and $2BaO \cdot SiO_2$.

238. H. F. Krause and W. Weyl, "Studies of the System Na_2O–BaO–SiO_2–CO_2: I, Reactions Between Na_2CO_3, $BaCO_3$, and SiO_2 in the Solid State," *Z. Anorg. & Allgem. Chem.*, **163**, 355–66 (1927).—The authors studied the reactivity of powdered quartz with $BaCO_3$, with and without the addition of Na_2CO_3 and before the mixtures began to melt. When mixtures of quartz and $BaCO_3$ are heated in a stream of CO_2, evolution of CO_2 begins noticeably at about 700°C. (1292°F.). For mixtures in which $BaO : SiO_2$ is greater than 2:1, the ratio $BaO : SiO_2$ in the reaction product is 2:1. In mixtures richer in SiO_2 the $BaCO_3$ reacts with a greater proportion of SiO_2 but not in stoichiometrical ratios. When the per cent SiO_2 is greater than that for $BaO : 3SiO_2$ the amount of SiO_2 which reacts may be greater than that required by the ratio $1BaO : SiO_2$. Explanations are suggested for the difference in reactivity of mixtures high and low in silica. The addition of Na_2CO_3 to mixtures of BaO and SiO_2 lowers the temperature of noticeable CO_2 evolution to about 400°C. (752°F.), and the composition of the reaction product depends on the composition of the mixture heated. For the isothermal heating of $BaCO_3$-SiO_2 mixtures at 750°, 850°, and 950°C. (1382°, 1562°, and 1742°F.), the amount of CO_2 evolved is closely proportional to the logarithm of the duration of heating. This also holds for mixtures containing Na_2CO_3.

239. F. M. Jager and H. S. van Klooster, "Researches in the Chemistry of the Silicates," *Sprechsaal*, **52**, 256 (1919); *Jour. Soc. Glass Tech.*, **3**, 234–36.—The silicates were prepared by first heating a mixture of quartz and the metal carbonate or oxide to the sintering point in a Pt dish in an electric oven and then completing the fusion in a Fletcher gas furnace. The silicates of Ba, Sr, Be, Zn, and Cd were white and crystalline. $2SrO \cdot SiO_2$ had a melting point of over 1750°C. (3182°F.); $2BaO \cdot SiO_2$ had a melting point of 1750°C.

PATENTS

240. C. Deguide, "Barium Hydroxide and Silicate," Fr. 483,044, May 23, 1917; Brit. 110,537, July 10, 1917.—Barium carbonate is calcined with SiO_2 at 1400° to 1500°C. (2552° to 2732°F.) in the proportion to produce $2BaO \cdot SiO_2$. The product obtained, which is not fused, is decomposed by means of H_2O, with the production of $BaO \cdot SiO_2$ and $Ba(OH)_2$. The $2BaO \cdot SiO_2$ is obtained by calcining at 1400° to 1500°C. (2552° to 2732°F.) a mixture of SiO_2 and $BaCO_3$ or a mixture of $BaO \cdot SiO_2$ and $BaCO_3$.

241. Rhenania-Kunheim Verein Chemischer Fabriken A.-G., "Barium Orthosilicate or Trisilicate," Fr. 636,045, June 16, 1927.—Ba orthosilicate or trisilicate is prepared by heating $BaCO_3$ with silicic acid or Ba metasilicate in the presence of steam, thereby lowering the temperature necessary. The steam may be led in with the furnace gas, or a gas containing sufficient H to form the necessary steam may be added.

242. Rhenania-Kunheim Verein Chemischer Fabriken A.-G., "Barium Silicate in Glass Manufacture," Brit. 259,953, Oct. 16, 1925.—A Ba silicate such as can be prepared by heating finely ground barytes, 100 parts, with quartz sand, 13 parts, in a revolving furnace with steam at 1200°C. (2192°F.) is used as a glass batch material; a batch may comprise, e.g., sand 100, Na_2CO_3 26, $CaCO_3$ 15, and Ba silicate 34 parts.

243. International Industrial and Chemical Co., Ltd., "Barium Compounds," Fr. 670,267, Feb. 25, 1929.—Ba silicates or mixtures of compounds containing silicates and oxide of Ba are made by calcining the starting materials, e.g., SiO_2, $BaSO_4$, and C, fusion being avoided by diluting or dispersing the materials in an agent infusible at temperature of calcination, preferably $BaO \cdot SiO_2$, so as not to introduce other substances into final product.

244. S. Wittouck, "Barium Silicates," Brit. 312,975, March 3, 1928; Ger. 553,236, March 24, 1928; U. S. 1,869,454, Aug. 2, 1932.—In producing silicates such as di- or tri-barium silicates by calcining silica or monobarium silicate with $BaSO_4$ at 1500°C. (2732°F.), with or without the presence of C or CO, fusion is avoided by the addition of a diluent (such as a quantity of the desired product) which is not fused under the conditions of the calcination. S, H_2SO_4, or CO_2 may be recovered in the process.

245. F. Rothe and H. Brenek, "Producing Other Compounds from Barium and Strontium Sulfates," U. S. 1,772,269, Aug. 5, 1930.—Ba and Sr sulfates are mixed with SiO_2 in such proportion that silicates of a type between $2BaO \cdot SiO_2$ or $2SrO \cdot SiO_2$ and $3BaO \cdot SiO_2$ or $3SrO \cdot SiO_2$ are formed and mixture is heated in an oxidizing atmosphere in the presence of steam to 1100°C. (2012°F.) or higher. Water forms $Ba(OH)_2$ in good yield from product.

246. F. Rothe and H. Brenek, "Barium Silicates," U. S. 1,824,298, Sept. 22, 1931.—Ba orthosilicate and Ba trisilicate are produced by heating $BaCO_3$ together with silica-containing material in the presence of steam.

247. C. E. Williams and J. D. Sullivan, "Basic Refractory and Method of Making," U. S. 1,954,552, April 10, 1934.—A basic refractory material which is resistant to slags and glasses is formed of commercial grades of calcined magnesite and witherite or dolomite and witherite fused in the electric furnace and cast in various types of molds. It can be used in the cast state or as a ramming mixture or cement. Fused masses of MgO and BaO do not slake in air, and mixtures containing 35% or less of BaO do not slake or disintegrate even after remaining under water for several weeks.

248. J. D. Sullivan, "Refractory Material Suitable for Furnace Linings," U. S. 2,160,923, June 6, 1939.—The refractory material is prepared by mixing raw magnesite, BaO, and SiO_2 and heating to a high temperature in order to impregnate and coat the magnesia particles with barium silicate. MgO is used with a total of 5 to 35% of BaO and SiO_2. The molecular ratio of BaO to SiO_2 is not greater than 2 to 1.

249. J. D. Sullivan, "Refractory Material Suitable for Furnace Linings," U. S. 2,160,924, June 6, 1939.—The refractory material is prepared by mixing raw magnesite, BaO, and SiO_2 in such proportions that on subsequent heating the resulting product will have MgO as its principal constituent and from 2 to 35% BaO and SiO_2 with a molecular ratio of the BaO to SiO_2 of not more than 2 to 1.

Strontium Orthosilicate

250. G. Stein, *Z. Anorg. Chem.*, **55**, 159–74 (1907); from Mellor,* Vol. 6, p. 353.—S. melted 2SrO and $1SiO_2$ in a carbon tube and obtained only the metasilicate and carbide, but when a porcelain tube was employed, large, doubly refracting, biaxial crystals of $2SrO \cdot SiO_2$ were obtained. No evidence of polymorphic forms was obtained by heating the crystals between 990° and 1634°C. (1814° and 2973°F.), by slow cooling, or by melting with SrO_2. The salt did not show the phenomenon of dusting exhibited by $2CaO \cdot SiO_2$. See reference No. 178, p. 287.

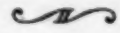
251. Pentti Eskola, "Silicates of Strontium and Barium," *Amer. Jour. Sci.*, [5]**4**, 331–75 (1922).—

* J. W. Mellor, Comprehensive Treatise on Inorganic and Theoretical Chemistry. Longmans, Green & Co., Ltd., London, 1925.

Mixtures were made of pure quartz, $CaCO_3$, $BaCO_3$, and $SrCO_3$. These substances were dried at 150°C. (302°F.) before weighing, mixed together, melted if possible, chilled, crushed, reheated, and ground twice more. The equilibrium relations were ascertained almost exclusively by the quenching method. The eutectic $SrO \cdot SiO_2$–$2SrO \cdot SiO_2$ was located at 65.5% SrO, as is apparent from the diagram. The steep slope of the liquidus curves at both sides is remarkable. While in the 65% SrO mixture the primary phase is $SrO \cdot SiO_2$, it is $2SrO \cdot SiO_2$ in the 67% SrO mixture, and the liquidus has risen 60°C. (108°F.) above the eutectic temperature, 1545°C. (2813°F.). The existence of $3SrO \cdot 2SiO_2$ is not proved. The primary phase in all the mixtures between the eutectic at 65.5% SrO and $2SrO \cdot SiO_2$ is strontium orthosilicate. The following experiments were carried out in order to establish whether there might be formed the compound $3SrO \cdot 2SiO_2$, analogous to $3CaO \cdot 2SiO_2$, known from the studies on the calcium silicates. Strontium carbonate and quartz powder, well mixed together, in the proportion required to form $3SrO \cdot 2SiO_2$ (72% SrO) were held 2 hr. at 1475°C. (2687°F.) and quenched. The product consisted of $SrO \cdot SiO_2$ and $2SrO \cdot SiO_2$. Another time the charge was allowed to cool slowly. The result was the same. The same mixture was heated 16 hr. at 1150°C. (2102°F.). It was now so fine-grained and poorly individualized that it could not be decided whether there were one or two phases present. Neither $SrO \cdot SiO_2$ nor $2SrO \cdot SiO_2$ could be identified. The melting point of strontium orthosilicate ($2SrO \cdot SiO_2$) is far above the range of the platinum resistance furnace. In a search for several polymorphic forms of this compound E. heated a preparation of crystalline $2SrO \cdot SiO_2$ at different temperatures: 5 min. at 1634°C. (2973°F.), and 2 hr. at 1415°C. (2579°F.), 1300°C. (2372°F.), and 990°C. (1814°F.). The result was always the same form, well characterized by its refringence and twinning. It was also obtained from a $SrCl_2$ melt at about 1000°C. (1832°F.). The substance did not change when allowed to cool very slowly. The phenomenon of "dusting" in the case of $2CaO \cdot SiO_2$ apparently has no analogue here. For the determination of the optical properties the preparation quenched from 1634°C. (2973°F.) was used, with the following result: alpha 1.7275 (D), beta 1.732 (D), and gamma 1.756 (D). The crystals are optically positive with $2E = 58°$ approximately or $2V = 32°30'$. In many of the crystals a twinning, often repeated, was observed. In sections normal to gamma, the acute bisectrix, the trace of the axial plane forms angles of 17° with the composition planes of the twinning lamellas. If the crystal system is monoclinic, the plane of the optic axes is normal to the plane of symmetry. The repeatedly twinned crystals, in their outlines, often display the habit of orthorhombic crystals, and when the lamellas are very narrow they have apparent straight extinction. All the mixtures which contained more strontium oxide (SrO) than $2SrO \cdot SiO_2$, resulted in two phases, $2SrO \cdot SiO_2$ and SrO, when heated at high temperatures. In these mixtures the strontium oxide could always be identified from its isotropic character and high index of refraction. See also reference No. 232, p. 291.

FORTY-THIRD ANNUAL MEETING, AMERICAN CERAMIC SOCIETY

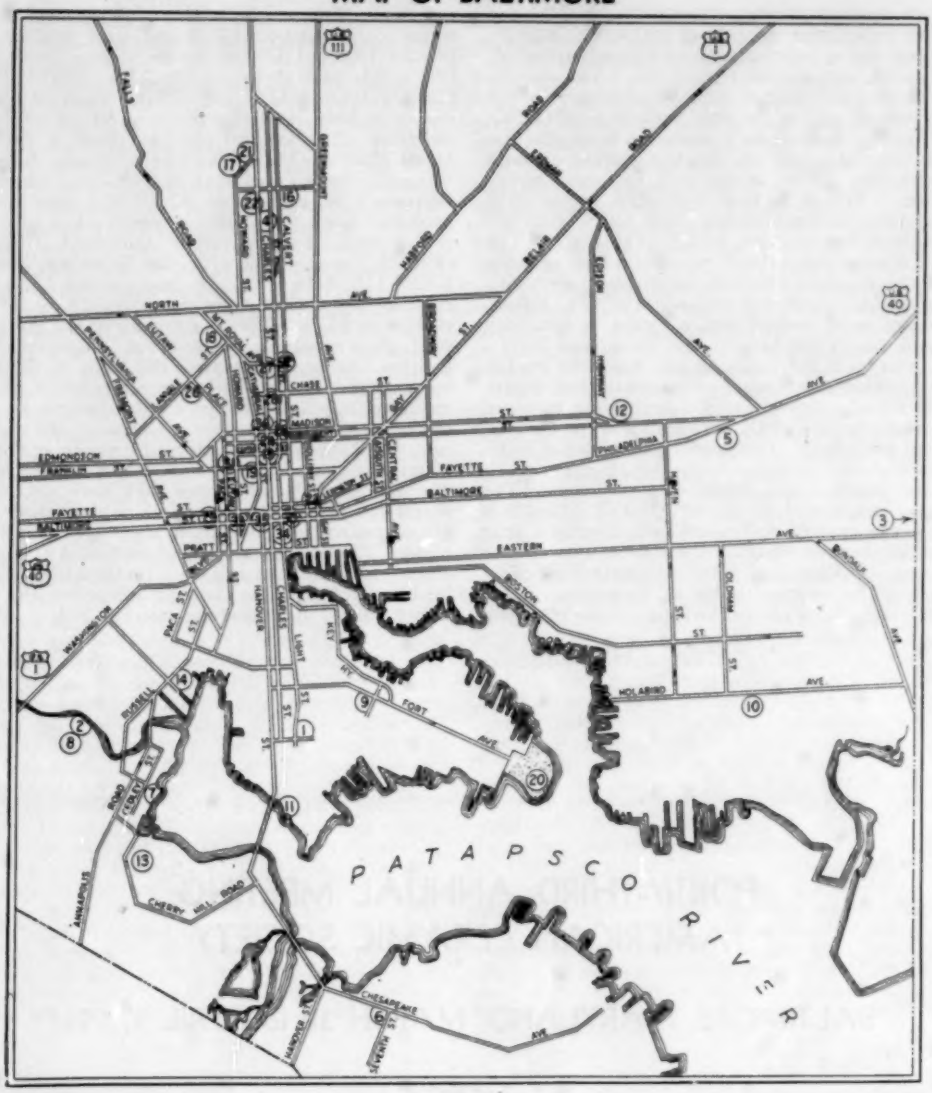
BALTIMORE, MARYLAND, MARCH 30 to APRIL 5, 1941



BALTIMORE HOTELS

The true test of a meeting city is not only the number of its hotels but their quality. Baltimore, with a tradition of hospitality founded on good food and good service, enjoys an established reputation in accommodating visitors to the city and making them feel at home. A reputation for the enjoyment of living has made Baltimore a haven for travelers. Baltimore has several consistently good hotels. The larger hotels are all located within a radius of a few blocks.

MAP OF BALTIMORE



(1) National Enameling and Stamping Co., 1901 Light St.
(2) Baltimore Enamel & Novelty Co., Mt. Winans.
(3) Porcelain Enamel & Mfg. Co., Eastern and Pemco Aves.
(4) Severn Ceramic Studio, 2618 St. Paul St.
(5) Harry C. Weiskittel Co., Inc., 4901 Philadelphia Rd.
(6) General Refractories Co., 701 Chesapeake Ave.
(7) Carr-Lowrey Glass Co., Westport.
(8) Maryland Glass Corp., Mt. Winans.
(9) Buck Glass Co., Fort Ave. and Lawrence St.
(10) American Radiator & Standard Sanitary Corp., 5315 Holabird Ave.
(11) Locke Insulator Corp., Charles and Hanover Sts.
(12) Baltimore Brick Co., 3601 E. Monument St.
(13) Westport Paving Brick Co., Westport.
(14) Swindell Bros., Inc., Bayard and Russell Sts.
(15) Walters Art Gallery, Charles and Centre Sts.
(16) Chen Chao Ming (Chinese Antiques), 339 E. 29th St.
(17) Baltimore Museum of Art, Charles St. and Art Museum Dr.
(18) Maryland Institute, Mt. Royal Ave. and Lanvale St.
(19) Enoch Pratt Free Library, Mulberry and Cathedral Sts.
(20) Fort McHenry and Marine Museum, foot of Fort Ave.
(21) Johns Hopkins University, North Charles and 33rd Sts.
(22) Maryland Academy of Sciences, North Charles and 27th Sts.
(23) Municipal Museum (Peale's), Lexington St. and Holliday.
(24) Washington Monument, Mt. Vernon Place.
(25) Abbey Hotel, St. Paul and Madison Sts.
(26) Altamont Hotel, Eutaw Place and Lanvale St.
(27) Arundel Hotel, Charles St. and Mt. Royal Ave.
(28) Belvedere Hotel, Charles St. at Chase.
(29) Biltmore Hotel, Paca and Fayette Sts.
(30) Emerson Hotel, Baltimore and Calvert Sts.
(31) Congress Hotel, Franklin and Howard Sts.
(32) Mt. Royal Hotel, Mt. Royal Ave. and Calvert St.
(33) New Howard Hotel, Howard and Baltimore Sts.
(34) Southern Hotel, Light and Redwood Sts.
(35) Lord Baltimore Hotel, Baltimore and Hanover Sts.
(36) Stafford Hotel, Charles and Madison Sts.

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